THE NICKEL BULLETIN

A MONTHLY SUMMARY OF CURRENT INFORMATION

APRIL, 1956

	Page
General	
Nuclear Power Plant	56
Calculation of Gamma Radiation Induced in Reactor Materials	56
Pickling of Metals and Alloys	56
Forming of Cermets by Low-Frequency Vibration	56
Metals used in Glass	56
Nickel	
Mining Industry of Canada, 1945-1954	57
Safety Practices in Nickel Mines	57
Nickel: Statistics for 1953	57
Nickel and Nickel Alloys made by Powder Metallurgy	57
Effect of Cold Work on the Properties of Nickel Wire	58
Reaction between Nickel and Ethylenediamine Solutions	59
Raney Nickel Catalysts in Production of Methane	59
Determination of Magnesium in Nickel	60
Absorptiometric Determination of Nickel	60
Magnetic Properties of Colloidal Nickelous Oxide	60
Magnetic Characteristics of the System NiO-Al_2O_3	60
Degradation of Oil-Extended Polymers Resulting from Metal Salts	60
Electrodeposition and Other Coating Methods	
Electroplating Handbook for Engineers	60
Structure of Electrodeposited Nickel	61
Levelling in Nickel Plating	61
Bright Nickel-Plating Solutions	61
Nickel-Coated Airscrew Blades	61
Coatings used as Substitutes for Nickel	62
Nickel and Nickel Alloys in Waveguide Devices	62
Vapour Plating of Metals	62
Non-Ferrous Alloys	
Constitution of Alloys: Bibliography	62
Nickel-Copper-Aluminium Alloys	62
Nickel Aluminides	63
Control of Quality in Production of Wrought Non-Ferrous Materials	63
Oxidation of Nickel-Carbon Alloys	63
Properties of Nickel-Tungsten Alloys produced by Powder Metallurgy	63
Effect of Neutron Irradiation on Precipitation Hardening in Nickel-Beryllium Alloys	64
Ferromagnetic Resonance in Nickel and Nickel Alloys	64
Nickel Alloys showing High Secondary-Emission Characteristics	65
Nickel and Nickel Alloys for Pressure Vessels	65
Nickel-containing Coinage: Royal Mint Report	66
Nickel-Iron Alloys	
Nickel-Alloy Magnets in Meters	66
Cast Iron	
S.G. Iron: Properties and Uses	66
Heat-Treatment of S.G. Iron	66
Machining and Grinding of S.G. Iron	66
Notch-Ductile High-Strength S.G. Irons	66
S.G. Iron Piping	67
Constructional Steels	
Ultra-High-Strength Nickel-Alloy Steels	67
German Standard Alloy Steels	68
Welding of Carilloy Steel	68
Difluorodichloromethane as Boundary Lubricant	68
Heat- and Corrosion-Resisting Materials	
American High-Temperature Alloys	69
Chemical Polishing and Etching of Nimonic Alloys	70
Rolling of Stainless Steel from Powder	70
Mass Transfer of Metals in Molten Lead	71
Resistance of Nickel-containing Materials to Sulphur Dew-Point Corrosion in Gases	71
Corrosion of Stainless Steel by Fuming Nitric Acid	73
„ „ „ „ in Ferric-Chloride Solutions	73
Handbook on Nickel-Chromium Stainless Steels	73
Nickel and Nickel Alloys in Petrochemical Plant	74
Nickel Alloys in Hydrochloric-Acid Plant	74
Galvanic-Couple Corrosion Data for Titanium	75
Ultrasonic Testing of Stainless-Steel Tubing	75
Properties of Modified Austenitic-Steel Weld Metal	75
Welding of Austenitic Steel Piping and Tubing	77
Hot Cracking in Austenitic Steel Welds	78
Nickel-Chromium Alloy Coating of Exhaust Valves	79
Nickel-Chromium-Boron Coatings	79
Patents	80

VOLUME 29 **NUMBER 4**

THE MOND NICKEL COMPANY LTD • THAMES HOUSE, MILLBANK, LONDON, S.W.1
Telephone:- Victoria 3888

ABSTRACTS OF CURRENT PUBLISHED INFORMATION ON NICKEL AND ITS ALLOYS

GENERAL

Nuclear Power Plant

UNITED NATIONS: 'Proceedings of the International Conference on the Peaceful Uses of Atomic Energy. Volume 3, Power Reactors.'

Published by *United Nations, New York*, 1955; 389 pp.

Available from Her Majesty's Stationery Office, London. Price 54/-.

This volume, covering Sessions 10A.2, 3.1, 11A, 12A, 13A, 14A of the Conference, contains papers and discussion relating to experience with nuclear power plants; fuel cycles; design of reactors for power production; power reactors, prototypes.

Calculation of Gamma Radiation Induced in Reactor Materials

C. D. BOPP and O. SISMAN: 'How to Calculate Gamma Radiation Induced in Reactor Materials.'

Nucleonics, 1956, vol. 14, Jan., pp. 46–50.

Report of measurements of gamma activity induced in various structural and reactor materials irradiated in the Oak Ridge National Laboratory, Oak Ridge, Tennessee. From the data tabulated it is possible to make a reasonably good estimate of the activity induced in materials exposed in other reactors under similar conditions: two limitations which must be recognized in applying the values to exposure in other types of reactor are indicated. (Some comparison is made with activity values obtained by calculation from the chemical composition of materials and the neutron cross section data available in the literature. It is observed that in most cases values obtained by the two methods are in good agreement.)

The tabular data obtained from the O.R.N.L. exposures include information on iron alloys of various types, carbon steels, nickel, nickel-molybdenum-base alloys, nickel-silicon-base alloy, nickel-chromium - iron alloy, precipitation - hardenable nickel-copper alloy, nickel-chromium stainless steels, aluminium alloys, beryllium, cadmium, copper, lead, niobium, titanium, thorium, ferro-tungsten, zirconium, concretes and graphites.

Pickling of Metals and Alloys

D. J. FISHLOCK: 'Pickling Processes Reviewed.'

Product Finishing, 1955, vol. 8, Nov., pp. 61–71, 110; Dec., pp. 52–68, 104; 1956, vol. 9, Jan., pp. 72–85, 124; Feb., pp. 84–97; Mar., pp. 70–8.

The five sections of this review which have already been published deal, respectively, with pickling methods in general and the various reagents used; plant employed in pickling; pickling of ferrous materials; pickling of stainless steels, and high-nickel nickel-copper and nickel-chromium alloys; treatment of copper and its alloys.

Forming of Cermets by Low-Frequency Vibration

W. C. BELL, R. D. DILLENDER, H. R. LOMINAC and E. G. MANNING: 'Vibratory Compacting of Metal and Ceramic Powders.'

Jnl. Amer. Ceramic Soc., 1955, vol. 38, Nov., pp. 396–404.

The investigation reported had two major objectives: (1) development of vibratory-compacting methods for formation of non-plastic powders (it was stipulated that no plasticizers or binders were to be used and that if possible the powders were to be formed in the dry condition) and (2) study of the influence of a wide range of particle-size distributions, on the properties of the as-formed specimens. Three compositions were used: Al_2O_3; 30% Cr with 70% Al_2O_3; and 15% Ni with 85% TiC. Identical compositions were formed also by conventional hydrostatic forming methods; full details are given of the two methods of compacting, and of the properties of the composites formed.

The results are considered by the authors to indicate that the low-frequency vibrational method of compacting offers considerable promise. Specimens formed by this procedure show properties approximately similar to those of compacts formed by dry pressing followed by hydrostatic re-pressing. It is urged that the low-frequency vibrational method has the following advantages: (*a*) no binder is required, (*b*) the method is considerably faster, on a laboratory scale, than hydrostatic forming, (*c*) less equipment is required, and (*d*) intricate shapes which normally would require complicated dry-press dies and elaborate forming techniques can be formed in one operation. It is noted that optimum vibratory compacting procedure varies according to the composition of the powders and their particle-size distribution, and that the latter variable has a considerable influence on as-formed density.

Metals Used in Glass

H. MOORE: 'Selenium, Tellurium, Cobalt and Nickel in Glass Making.'

Mond Nickel Co., Ltd., Publn. 897,* 1956; 40 pp.

The four elements selenium, tellurium, cobalt and nickel, or their compounds, are used in glass making as colouring media: selenium, cobalt and nickel may also be used for decolourizing. This brochure

* *We shall be pleased to supply a free copy of this publication.*

opens with a brief outline of the early history of glass making, notes on the three principal types of glass used for domestic ware, and a short description of methods employed for colouring glass. The introduction is followed by chapters describing the use made of the four elements mentioned, for various types of glass. The effects producible are demonstrated by a series of coloured illustrations showing the many grades of blue, red, purple, yellow and other hues which result from the use of the respective metal compounds.

Ultrasonic Testing of Tubing

See abstract on p. 75.

Difluorodichloromethane as Boundary Lubricant

See abstract on p. 68.

NICKEL

The Mining Industry of Canada, 1945-1954

H. A. GRAVES: 'A Decade of Progress in Canadian Mining (1945–1954).'

Trans. Instn. Mining and Metallurgy, 1954–55, vol. 64, pp. 349–73; 1955–56, vol. 65, pp. 113–45.

This paper reviews some of the advances made by the Canadian mining industry, in expansion of production and in increased efficiency, as a result of development of technical and operational refinements in mining practice. The first part of the report deals with the general growth of the industry, drawing attention to some of the improved methods of surveying and establishment of new mines which have been responsible for the growth of the industry. The second part reviews the many improvements in technique and equipment which have been introduced in drilling, blasting, shaft sinking, hoisting, stoping, transportation and other operations. It is pointed out that such developments have helped to make possible exploitation of some of the leaner and more complex deposits, which could not have been economically worked by methods employed in earlier years. Considerable reference is made to the activities of The International Nickel Company, in the Sudbury region and elsewhere, and to work carried out by other Companies concerned with the mining of nickel-containing ores.

Safety Practices in Nickel Mines

A. E. O'BRIEN: 'Safety Practice at the Mines and Reduction Plants of the Mining and Smelting Division of the International Nickel Company of Canada, Limited.'

Trans. Canad. Inst. Mining and Metallurgy, 1956, vol. 59, pp. 4–13: *Canad. Mining and Metallurgical Bull.*, 1956, vol. 49, Jan., pp. 6–15.

Detailed description of methods adopted for prevention of accidents, and of first-aid work which minimizes length of lost time due to sickness. A chart shows that accident frequency, per 1,000 shifts worked, has dropped from 0·14 in 1930 to 0·028 in 1954 and sickness time from 1,087 days per 1,000 shifts to 1·73 days in 1954.

Nickel: Statistics for 1953

H. W. DAVIS: 'Nickel.'

Preprint from *U.S. Bureau of Mines Minerals Yearbook*, 1953. Published by *U.S. Government Printing Office, Washington* 25, *D.C.*, 1955; 17 pp.

The review contains statistics on world production, consumption, prices, etc., together with breakdown of U.S. imports and exports for 1953. Some comparisons are made with earlier years. Recent developments in technology, and progress in mining and extraction methods in various countries are also reviewed.

Nickel and Nickel Alloys made by Powder Metallurgy

HENRY WIGGIN AND CO., LTD.: 'Wiggin Nickel Alloys by Powder Metallurgy.'

Publn. 890A*, 1955; 20 pp.

Powder metallurgy is now well established commercially as a technique for production of metals and alloys required for specialized uses. The application of such methods has been found to offer a number of advantages in manufacture of nickel and nickel alloys in which particularly high purity and closely controlled properties are essential. This brochure gives the compositions and properties of various grades of nickel and of nickel alloys made from carbonyl nickel and iron powders (which are intrinsically of high purity) and containing also, in some cases, cobalt and molybdenum powders prepared by hydrogen-reduction of pure oxides, and copper powder produced by atomization of O.F.H.C. copper.

Manufacture of bulk material by powder-metallurgical methods makes possible retention, in the finished product, of a purity at least equal to that of the constituent powders, and in some cases it may even be enhanced, due to removal of oxygen and carbon during processing.

The publication gives some account of the methods used in preparation of strip, rod and wire from nickel and nickel alloys, the specifications to which such materials can be consistently produced, and a brief review of some of the applications in which the high and controllable properties of these materials are utilized, e.g., in electronic equipment, in alloys required to show special expansion characteristics, and in magnetic alloys. Materials for which the powder-metallurgy method of production is now in regular use include five grades of nickel (H.P.M., H.P.A., H.P.B., O, and G.F.A.), controlled-expansion alloys of nickel-iron and Nilo K (nickel-cobalt-iron) types, and high-permeability nickel-iron alloys containing small amounts of molybdenum and copper.

* *We shall be pleased to supply a free copy of this publication.*

Ferromagnetic Resonance in Nickel and Nickel Alloys

See abstract on p. 64.

Calculation of Gamma Radiation Induced in Reactor Materials

See abstract on p. 56.

Control of Quality in Production of Wrought Non-Ferrous Materials

See abstract on p. 63.

Effect of Cold Work on the Properties of Nickel Wire

G. A. NELSON: 'The Effect of Cold Reduction on Some Properties of Nickel Wire.'

Wire and Wire Products, 1955, vol. 30, Nov., pp. 1355–8, 1417–18.

This paper reports tests made by Sylvania Electric Products, Inc., in connexion with the use of nickel wires in electronic-tube applications, for which increasingly stringent specifications with regard to composition and properties are being laid down. The main object of the tests was to assess the influence of cold work on mechanical properties.

The materials studied were three grades of metal which, whilst all basically pure nickel, vary in type and the amounts of the minor constituents present, and differ to a considerable degree in their mechanical properties and in the processing procedure which gives the best results. Typical compositions of the three nickels are shown in the table below:—

Material	Ni + Co %	Mn %	C %	Ti %
'A' Nickel ..	99·0 min.	0·35 max.	0·20 max.	—
'D' Nickel ..	93·7	4·5—5·0	0·20 max.	—
Permanickel ..	97·0	0·50 max.	0·40 max.	0·2—0·6

Grade 'A' nickel is a commercially pure metal, produced by melting and deoxidizing electrolytic nickel. It is particularly suitable, in wire form, for electron-tube supports, grid side rods, and base pins. 'A' nickel has a high degree of corrosion-resistance, and sufficient mechanical strength to withstand the high temperature to which it is exposed during outgassing in the tube-manufacturing process: it has a sufficiently low specific resistivity (about 57 ohms per circular mil. foot at 32°F.) to permit its use as a current-carrying lead. This grade of nickel is, however, very sensitive to intergranular attack when exposed to atmospheres containing even minute amounts of sulphur, such as may be present in annealing atmospheres or in the gas flames used to seal glass in tube-manufacturing operations.

'D' nickel, due to its high manganese content, has a better tolerance for sulphur-contaminated atmospheres, and in the annealed condition has a slightly higher strength and hardness than those characteristic of 'A' nickel. An application for which 'D' nickel is particularly suitable is grid lateral wire, since the electron emission of this material is much lower than that of 'A' nickel. The electrical resistivity of 'D' nickel is about 110 ohms per circular mil. foot at 32°F.

In Permanickel, although the composition is in some respects closer to that of 'A' nickel, the small addition of titanium and the increased carbon content make the alloy precipitation-hardenable, with resultant marked differences in hardness, workability, annealing characteristics, and mechanical properties. Typical applications for this material are grid lateral and grid side rod wires, particularly where very small closely wound grids with maximum rigidity and freedom from vibration are required.

The wire samples for the test were obtained by cold drawing wire of small diameter through standard wire-drawing dies, to reduce the cross-sectional area by pre-determined percentages. Cold reduction varying up to a total of 98 per cent. was investigated. Full details are given of the experimental drawing conditions.

The properties determined, as a function of cold working, were tensile strength, yield strength, elongation, and a property designated 'working range', which is used in the electronics industry to define the difference in load per unit area between the yield strength at one per cent. elongation and the tensile strength. It represents the range of loads which may be applied to a wire between the point at which it is permanently deformed and the point at which rupture occurs. The property is considered particularly important in the winding of electron-tube grids, where tube characteristics are dependent on maintaining very close tolerances in grid shapes. The results of the respective tensile properties are graphically shown, and photomicrographs illustrate the effect of cold reduction and of annealing temperature on the structure of the respective wires.

From the observations made, the following general conclusions are deduced:—

Reduction percentages below 60 usually caused non-uniform properties after annealing. In the low range of reduction annealing temperatures required to obtain a given tensile strength were higher than those necessary to give the same strength in materials which had been cold worked to a reduction of more

than 50 per cent. Maximum uniformity of mechanical properties was found in the range of reduction between 60 and 95 per cent. for 'A' nickel, between 60 and 90 per cent. for 'D' nickel, and between 60 and 85 per cent. for Permanickel. With Permanickel specially close control of annealing temperature was necessary to produce uniformity of mechanical properties, due to a tendency to rapid grain growth in the critical annealing-temperature range. Maximum stability of yield strength was found to correspond to the reduction percentages giving the most uniform tensile properties, and the best working-range characteristics were also obtained in these conditions. For all three materials, the best elongation figures were associated with reductions between 70 and 85 per cent., and in general it was noted that higher elongations were found in materials annealed at the minimum temperature required to give the desired tensile and working-range properties.

Reaction between Nickel and Ethylenediamine Solutions

T. L. KEELEN and R. C. ANDERSON: 'Surface Interaction between Metallic Nickel and Ethylenediamine Solutions.'

Jnl. Physical Chemistry, 1955, vol. 59, Sept., pp. 881–4; disc., pp. 884–5.

Rates of solution were measured for metallic nickel in basic solutions of ethylenediamine, diethylenetriamine and triethylenetetramine in water or methanol. Comparative rates show that the solution is not simply a result of decreased nickel-ion concentration because of complex formation, but that it involves rather a surface reaction of the amines. It was found that appreciable reaction could occur in the absence of oxygen. Other results indicate that adsorption of both water and the amine are necessary for the surface reaction.

Nickel and Nickel Alloys for Pressure Vessels

See abstract on p. 65.

Nickel-containing Coinage: Royal Mint Report

See abstract on p. 66.

Raney Nickel Catalysts in Production of Methane

M. D. SCHLESINGER, J. J. DEMETER and M. GREYSON: 'Catalyst for Producing Methane from Hydrogen and Carbon Monoxide.' *Industrial and Engineering Chemistry*, 1956, vol. 48, Jan., pp. 68-70.

This paper reports work in the U.S. Bureau of Mines, Bituminous Coal Branch, Pittsburgh.

Studies on the catalytic conversion of synthesis gas (H_2+CO) to methane involved testing of a large number of catalysts, in fixed and fluidized beds, to determine methanation activity and process life. The experiments were made as part of a programme of research on synthesis of high B.t.u. fuel gas from coal. The results showed that Raney nickel catalysts, if correctly prepared, are active and long-lived catalysts for dry-bed methanation. In addition to their high degree of reactivity, they have the advantage of permitting large throughputs of synthesis gas without excessive rise in temperature, even in fixed beds.

This paper describes methods used for preparation of the catalysts tested, and gives results of operation under synthesis conditions. The mode of catalyst preparation found most satisfactory consisted in crushing a 42–58 per cent. nickel-aluminium alloy to granules of the required size and immersion of the granules in sodium-hydroxide or potassium-hydroxide solution to extract the aluminium. The most successful results were obtained by using a solution containing only enough alkali to extract 3–5 per cent. of the aluminium. The extracted material was washed until the water gave a neutral reaction with litmus or pH paper. The catalyst, while still wet, was charged to the reactor and the water was removed by passing hot hydrogen through the catalyst bed. It was considered to be dry when, in fixed-bed tests, water ceased condensing in the liquid-recovery system, and in the fluidized bed when the motion of the differential pressure manometer indicated that the catalyst bed was fluidized.

It is concluded from the tests reported that, in both fixed and fluidized beds, only a small amount of active nickel surface is required for complete conversion of the synthesis gas. Because so little nickel surface needs to be exposed, the active material remains well bonded to the parent alloy. Attrition losses are, therefore, at a minimum and difficulties with fluidization, such as deaeration do not occur.

When the surface nickel is no longer catalytically active, it can be removed and a fresh surface generated by extraction. It is pointed out that it should be possible in this way to reactivate a bed of the catalyst until the extraction process yields particles of such small size that it is impractical to utilize them in the fluidized bed. The separated fines and spalled nickel could be used for further alloy preparation, thereby conserving the costliest element of the catalyst; by this method only aluminium, sodium or potassium hydroxide, and water would be consumed.

The experiments demonstrate that composition of the feed gas is an important factor. Equilibrium calculations indicate that when the ratio of hydrogen to carbon monoxide falls below about 2·6 it is possible to deposit carbon. On the other hand, when there is an excess of hydrogen the heating value of the product gas is reduced by the presence of unconverted hydrogen. The H_2:CO ratio used must therefore be evaluated carefully in terms of the heating value required and the degree of carbon deposition that can be tolerated.

Nickel and Nickel Alloys in Petrochemical Plant

See abstract on p. 74.

Vapour Plating of Metals

See abstract on p. 62.

Determination of Magnesium in Nickel

S. YOKOSUKA: 'The Analysis of Metallic Nickel. III. Determination of Magnesium.'

Japan Analyst, 1955, vol. 4, pp. 141–4;
Analytical Abstracts, 1956, vol. 3, Jan., Abs. 47.

Report of procedure developed for colorimetric determination of small amounts of magnesium in nickel, by use of Titan yellow. 'Nickel is removed by electrolysis in sulphuric-acid solution: interfering elements, e.g., copper, iron, lead, zinc, tin and cadmium, can be eliminated by adding potassium cyanide. The pink colour of magnesium in an aqueous solution of Titan yellow is markedly stabilized by adding starch solution as protective colloid.' Details of procedure are given in the abstract.

Absorptiometric Determination of Nickel

J. WINNING and S. MILLER: 'Determination of Nickel, Chromium and Molybdenum using the Spekker Absorptiometer.'

Metallurgia, 1956, vol. 53, Jan., pp. 50–2.

After emphasizing the usefulness of absorptiometric methods of analysis, the authors review some of the most recent modifications which have been made in this technique, and discuss, in particular, the limitations of perchloric acid as a reagent.

They then report tests made in the analysis of low-alloy steels of nickel-chromium-molybdenum types, using, in place of perchloric acid, 'Spekker acid' (150 ml. each of sulphuric and phosphoric acids to 1 litre of water), oxidized with nitric acid. Details are also given of other modifications of reagents found to give improved results in determination of chromium, nickel and molybdenum by this method. The procedures described are recommended as shortening the time required for analysis, effecting considerable saving in cost, eliminating risks attendant on use of perchloric acid, and avoiding heavy fumes in the laboratory.

Magnetic Properties of Colloidal Nickelous Oxide

J. T. RICHARDSON and W. O. MILLIGAN: 'Magnetic Properties of Colloidal Nickelous Oxide.'

Bull. Amer. Physical Soc., Ser. II, 1956, vol. 1, Feb. 24, p. 87, Abs. F.2.

Abstract of paper to American Physical Society, Feb., 1956.

Magnetic susceptibility measurements were made at 4° to 550°K. (−269° to +277°C.) on iron-free NiO prepared by heat-treatment of $Ni(OH)_2$ at 250°–1300°C. Crystal size of the material varied from 80 to 2000 Å. The principal conclusions drawn from the research are summarized in the abstract.

Magnetic Characteristics of the System NiO-Al_2O_3

W. O. MILLIGAN and J. T. RICHARDSON: 'Magnetic Susceptibility Studies in the Dual Hydrous Oxide System NiO–Al_2O_3.'

Jnl. Physical Chemistry, 1955, vol. 59, Sept., pp. 831–3.

Report of comprehensive investigation of the magnetic susceptibility of this system, made on 105 samples, prepared at every 5-mole per cent., and heat-treated at 300°, 400°, 500°, 600° and 700°C. The magnetic measurements were made at room temperature.

Metals Used in Glass

See abstract on p. 56.

Degradation of Oil-Extended Polymers Resulting from Metal Salts

J. M. MITCHELL, W. H. EMBREE and R. B. MACFARLANE: 'Degradation of Oil-Extended Polymers in Presence of Metal Salts.'

Industrial and Engineering Chemistry, 1956, vol. 48, Feb., pp. 345–8.

This paper deals mainly with the effect of iron in promoting breakdown of polymer-oil master batches, but the effect of other metal salts was also studied. Results indicate that polymer degradation is relatively insignificant with tin, zinc, and nickel, but increasingly severe with chromium, cobalt, iron, manganese, or copper.

ELECTRODEPOSITION AND OTHER COATING METHODS

Electroplating Handbook for Engineers

A. K. GRAHAM (Editor): 'Electroplating Engineering Handbook.' Published by *Reinhold Publishing Corpn., New York*, 1955; 650 pp. Price $10.

This Handbook, the various sections of which have been prepared by individual specialists in the respective fields, is designed essentially to meet the needs of the practical electroplater and the electroplating engineer concerned with design, installation and operation of plating plant and ancillary equipment.

Part I contains a collection of information considered necessary as a background for the electroplating engineer. This includes tables of data on chemical compounds associated with electroplating; compositions and properties typical of metals, alloys and steels; units and factors employed in this industry; conversion factors; standard gauge and size numberings, and other reference matter. This introduction is followed by chapters on design of parts for plating, preparation of surfaces, typical plating sequences, solutions and operating conditions for electrodeposition of various metals, standards and specifications governing plated products, analysis of solutions and testing of coatings, waste disposal, metal-finishing costs, and industrial hygiene. A review is made of metallurgical factors with which the plater should be familiar, as liable to influence operation of plating processes and the quality of the product obtained. The final chapters in Part I of the Handbook are concerned with various types of finishing treatment other than electrodeposition, e.g., phosphate and chromate coatings, and anodizing.

Part II is concerned entirely with the engineering

aspects: design and construction of plating installations and accessory plant, sources of current, semi- and fully-automatic plating units, barrels, exhaust systems, rinsing and drying equipment, filtering units, etc. Maintenance of buildings and equipment is also considered. Composition of anodes and cathodes, shapes, methods of fixing and other details are dealt with in another chapter of Part II.

The individual sections are preceded by a glossary of terms associated with the various branches of the electroplating industry, and all sections in the Handbook incorporate selected *bibliographies*.

Structure of Electrodeposited Nickel and Other Metals

R. WEIL and H. J. READ: 'The Structure of Electrodeposited Metals.'

Metal Finishing, 1955, vol. 53, Nov., pp. 60–5; Dec., pp. 60–4; 1956, vol. 54, Jan., pp. 56–9.

The paper is condensed from a thesis by the senior author, presented to the Graduate Faculty of the Pennsylvania State University. The complete thesis is available from University Microfilms, Ann Arbor, Michigan.

The research covered a study of the surface structure of deposits, using specimens of common coating metals plated onto electropolished rolled copper sheet. The baths used were representative types of

all-sulphate, all-chloride and Watts nickel solutions,
„ „ „ „ cobalt „
acid and cyanide copper solutions,
„ „ „ zinc „
„ „ „ cadmium „

The conditions varied within each series were those most practically important in commercial operation: current density, temperature, and, where applicable, pH.

In most cases a series of deposits of increasing thickness was made for each set of plating conditions for a given metal, starting with a thickness of 0·003 mil. and progressing in a geometric series to 0·63 mil. The electron microscope was used almost exclusively for study of the microstructure of the deposits.

From the large amount of experimental data recorded (for which the original publication must be consulted), it is concluded that the surface microstructures of the metals electrodeposited in the various conditions can be divided into two major types. Type I includes structures in which the individual crystals *do not* possess a distinct preferred growth direction in the plane of the surface; type II comprises structures in which the individual crystals *do* possess a definite preferred direction of growth in the plane surface. (The authors propose further sub-divisions within these two categories.) Type II electrodeposits are obtained only from zinc, cadmium, cobalt and all-chloride nickel baths. Certain anomalies in structures obtained from the all-chloride nickel solution are noted.

The observations made show that the structural type for any given deposit is reproducible, indicating that it is intrinsically a function of the bath and the plating conditions. Although the major portion of the investigation was concerned with the study of visual microstructures, the lattice structure of some representative nickel and cobalt specimens was determined. A theory proposed by the authors to account for the formation of the various types of structure is based on a consideration of the lattice structure of the plated metal and the quantity of growth-impeding material in the cathode film. It is suggested that the brightness of deposits is conditioned by the grain size and the orientation of the platelets in grains of any given size.

Levelling in Bright Nickel-Plating Solutions

K. E. LANGFORD: 'Levelling in Bright Nickel-Plating Solutions.'

Electroplating and Metal Finishing, 1956, vol. 9, Feb., pp. 39–43, 48; Mar., pp. 71–6.

Although there is an extensive literature on the practical aspects of bright nickel plating and on the mechanism of brightening, relatively little information is available on the types of compound which will act as brightening and levelling media.

In this review, an attempt is made to relate the chemical properties of certain organic compounds to their suitability as levelling agents in bright nickel-plating solutions. The substances to which main attention has been given are the heterocyclic bases and their quaternary alkyl derivatives. The writer discusses the preparation and properties of the quaternary compounds and the nature of nickel deposits produced from electrolytes in which they are present. Attention is directed to the relationship between the hardness and microstructure of deposits and the chemical constitution of the leveller agents in the baths from which they are made. The beneficial effect of surface-active agents in plating solutions is demonstrated: nitrogen is shown to be present in deposits made from such baths. The author proposes an explanation of the action of some levelling agents, and makes recommendations on the chemical control of solutions containing such additions.

Bright Nickel-Plating Solutions

'New Udylite Nickel Processes.'

Electroplating and Metal Finishing, 1956, vol. 9, Feb., p. 53.

This article refers to the No. 514 and No. 514H solutions of high levelling power, recently introduced into the United Kingdom by Electro-Chemical Engineering Company, Limited (see *Nickel Bulletin*, 1956, vol. 29, No. 3, p. 33). Details are given also of solutions designated 322 and 322H, which deposit a bright nickel coating of greater ductility than was obtainable from the Efco-Udylite No. 31 (sulphate-chloride) and 31H (high-chloride) solutions.

Nickel-Coated Airscrew Blades

'Nickel-Coated Airscrew Blades.' *Aircraft Production*, 1956, vol. 18, Mar., p. 89.

A method of protecting airscrew blades with a

thin layer of nickel (developed initially for the use of the U.S. Navy and Air Force) has been found to give effective protection against damage from stones, debris or water spray. The invention is the result of co-operative work between Hamilton Standard Division of United Aircraft Corporation of Connecticut and Bart Laboratories Company, Inc., of Belleville, New Jersey. The process, which involves the use of a synthetic-rubber compound to establish a bond between the base and coating metals, can be used to plate nickel on solid aluminium-alloy or hollow steel blades.

Service Experience with Coatings used as Substitutes for Nickel

A. K. GRAHAM: 'Proposed Substitutes for Nickel Plating.' *Plating*, 1956, vol. 43, Feb., pp. 218–20.

The summary contained in this article formed part of a paper presented before a Branch of the American Electroplaters' Society. The information given and opinions expressed are based on thirteen replies to a questionnaire sent to twenty-four representative producers and users of plated goods.

Nickel and Nickel Alloys in Waveguide Devices

D. S. HILLS and W. L. HIRSH: 'Metallurgy of T. R. Cell Production.'

Metal Treatment, 1956, vol. 23, Feb., pp. 72–4.

The article describes methods which have been jointly developed by the General Electric Company, Limited and one of its subsidiary Companies, for quantity production of T. R. Cells, a type of waveguide device used in high-frequency radar systems. The assembly is constructed from mild steel, on which a diffused copper coating is produced during a copper-brazing process, thus securing low-frequency-loss values similar to those which would be obtained by using non-ferrous metals for the unit. This article gives a step-by-step account of the fabricating processes, from forming of the steel waveguide case, through to final nickel plating of the finished brazed cell, to give added protection and to prevent contact potential of the cell during service. It is noted that for glass-to-metal seals involved in assembly a low-expansion alloy containing nickel 28, iron 53, cobalt 18 per cent. is used, to match, in thermal expansion properties, a borosilicate glass.

Vapour Plating of Metals

C. F. POWELL, I. E. CAMPBELL and B. W. GONSER: 'Vapour Plating: The Formation of Coatings by Vapour-Deposition Techniques.'

Sponsored by The Electrochemical Society, Inc., New York, N.Y.

Published by *John Wiley and Sons, Inc., New York; Chapman and Hall, Ltd., London*, 1955; 158 pp. Price 44/-.

It is noted that the term 'vapour plating' has been used to describe the purely physical methods of deposition, such as vacuum metallizing, and chemical processes such as hydrogen reduction or thermal decomposition of metal halides at heated surfaces. In this book the term is applied solely to the chemical techniques.

This monograph represents the first critical and authoritative review in which vapour plating (within the limits indicated) has been treated as a main subject. The aim has been to give a comprehensive description of past and currently used techniques and applications, and to provide a critical assessment of the present stage of development. Properties and uses of vapour coatings are discussed, and, in the light of extensive experience, the authors make suggestions for extending the applications of some of the techniques considered. The book includes information on vapour deposition of nickel by various methods, the co-deposition of nickel with other metals, and some reference to other metals deposited by vapour plating on a nickel base.

NON-FERROUS ALLOYS

Constitution of Alloys: Bibliography

A. PRINCE: 'The Constitutional Diagrams of Alloys: a Bibliography.'

Inst. Metals Monograph and Report Series No. 2, Second Edn. Published by the Institute 1956; 324 pp. Price: Members 17/6; Non-Members 35/-.

The first edition of the *bibliography* compiled by J. L. HAUGHTON, was issued by the Institute of Metals in 1942; the present volume is an amplification which brings the references to published literature up to the end of 1954 in as comprehensive manner as has been found possible, and, in some cases, includes material published in 1955.

The arrangement of the items is on the same plan as that used in the first edition: the systems are in alphabetical order of the chemical symbols of the metals composing them, and in each section the references are in chronological order. The *bibliography* has since 1942 been a standard work of reference, and its revision to so recent a date should eliminate much of the work involved in searching for constitutional data in a widely scattered literature.

Nickel-Copper-Aluminium Alloys: Structural Investigation

M. G. BOWN: 'The Structure of Rhombohedral *T* (NiCuAl).' *Acta Crystallographica*, 1956, vol. 9, Jan. 10, pp. 70–4.

The nickel-copper-aluminium system has been investigated by BRADLEY and LIPSON (1938) and by KÖSTER, ZWICKER and MOELLER (1948). Only one ternary compound was found, with composition field at 500°C. roughly a parallelogram defined by the lines 57·5 and 64 at. per cent. aluminium, 5·5 and 10 at. per cent. nickel. The phase has usually been given the formula $NiCu_3Al_6$: in the present paper the letter *T* is used. From powder photographs BRADLEY and LIPSON described the structure as 'distorted body-centred cubic'.

In the work now described crystals of the ternary compound were examined by single-crystal X-ray

methods. Two distinct forms were found, one having a rhombohedral, the other a cubic, unit cell. In both forms the heavy and light atoms are arranged as in a CsCl-type structure: ordered vacancies in heavy-atom sites give rise to the two different superlattices. The rhombohedral unit cell contains, ideally, 8 aluminium and 6 heavy atoms: in the crystals examined there were also random vacancies in the heavy-atom sites, and possibly in the aluminium sites. The relationship between the two forms is briefly considered.

Nickel Aluminides: Constitution and Properties

J. H. WESTBROOK: 'Temperature Dependence of Hardness of the Equi-Atomic Iron-Group Aluminides.' *Jnl. Electrochemical Soc.*, 1956, vol. 103, Jan., pp. 54–63.

As part of a general investigation of the strength of solids as a function of temperature, a study was made of iron-, cobalt- and nickel-aluminides. The work covered determination of hardness as a function of temperature and composition up to 800°C., over the entire homogeneity range of each of the compounds.

The data presented establish the fact that the temperature dependence of hardness of the equi-atomic iron-group aluminides does not follow the empirical rules which have previously been found valid for pure metals. The observations made indicate that hardness behaviour in the aluminides is related to the defect structure.

Control of Quality in Production of Wrought Non-Ferrous Materials

INST. METALS: 'The Control of Quality in the Production of Wrought Non-Ferrous Metals and Alloys. III. The Control of Quality in Heat-Treatment and Final Operations.'

Inst. Metals Monograph and Report Series No. 17; 104 pp.

Published by the Institute, 1955.
Price: Members 7/6; Non-Members 15/-.

This volume contains the final forms of papers presented at the symposium held in March 1955, together with discussion. For abstracts of papers see *Nickel Bulletin*, 1955, vol. 28, No. 4, pp. 62–3.

Pickling of Metals and Alloys

See abstract on p. 56.

Chemical Polishing and Etching of Nickel-Chromium Alloys

See abstract on p. 70.

Difluorodichloromethane as Boundary Lubricant

See abstract on p. 68.

Oxidation of Nickel-Carbon Alloys

W. W. WEBB, J. T. NORTON and C. WAGNER: 'Oxidation Studies in Metal-Carbon Systems.'

Jnl. Electrochemical Soc., 1956, vol. 103, Feb., pp. 112–17.

The paper opens with a general analysis of the oxidation characteristics of alloys containing carbon or carbides. The general principles governing the oxidation of metal-carbon systems are then illustrated by investigations on alloys in the nickel-, tungsten-, manganese-, and titanium-carbon systems. It is shown that evolution of gaseous carbon monoxide and carbon dioxide may rupture oxide films which are formed on such materials, and which, in the absence of carbon, would be highly protective. If, however, the metal alloyed with carbon has a high affinity for oxygen, carbon may be retained in the alloy, or may diffuse across the oxide layer. Tests on typical 'hard metals' indicated that the presence of carbon has only a relatively minor effect on the oxidation characteristics of titanium-carbide-base types.

Properties of Nickel-Tungsten Alloys Produced by Powder Metallurgy

M. DAVIS, C. E. DENSEM and J. H. RENDALL: 'The Manufacture and Properties of High-Strength Nickel-Tungsten Alloys.'

Jnl. Inst. Metals, 1955–56, vol. 84, Feb., pp. 160–4.

The authors describe work on a series of materials believed to be potentially useful in thermionic-valve construction. It is pointed out that conditions of operation today frequently involve mechanical vibration and shock and that, due to space considerations, there is a need for improved valves of small size and high performance. In the case of oxide-coated cathodes a metallic material having the following properties would be suitable:—

(i) High strength both at room temperature and at about 800°C.

(ii) Low thermal and electrical conductivities.

(iii) Capability of being made into thin-walled tubes and very thin wire and tape.

(iv) Low vapour pressure at the operating temperature, about 800°C.

(v) Compatibility with the barium-strontium oxide coating.

The work reported in this paper demonstrates that nickel-tungsten alloys containing 5–40 per cent. of tungsten, prepared by powder-metallurgy methods, can be cold worked to fine-gauge wire and strip suitable for use in valves, and that the mechanical and physical properties of the alloys are suitable for such applications. The strength of the alloys rises with increase in tungsten content, and age-hardening is producible by heat-treatment of those containing more than 30 per cent. of tungsten. Methods of preparation and processing are described. The properties of alloys examined are shown in the table on page 64.

The authors express the following views with regard to the spheres of application of the respective alloys of the nickel-tungsten series:—

'For exceptionally high-duty needs, the nickel-40 per cent. tungsten alloy offers outstanding advantages, in that it may be shaped in the annealed condition and then age-hardened at 700°–950°C., a range which

The Properties of Nickel-Tungsten Alloys compared with those of Nickel and of Tungsten

	Nickel (annealed)	5% W	Nickel-Tungsten Alloys					Tungsten
			10% W	20% W	30% W	40% W (solid solution)	40% W (aged ½ hr. at 900°C.)	
Density, g./c.c.	8·9	9·14	9·40	9·98	10·63	11·43	—	19·3
Thermal Conductivity (at 150°C.), cal./sec./cm./°C.	0·142	0·102	0·062	0·046	0·034	0·029	—	0·39
Thermal Expansion.. .. (20°–320°C.), $°C.^{-1} \times 10^6$	13·3	—	—	—	11·8	10·65	—	4·4
Electrical Resistivity, microhm. cm.: 2t								
at 20°C.	6·8	17	27	51	93	124	76	5·6
at 800°C.	44	53	62	84	106	—	102	27
at 1000°C...	49	59	69	89	109	131	—	33
Yield Stress, t.s.i.								
at 20°C.	9	11·0	13·5	22·7	32·5	49·8	75	200
at 800°C.	1	6·2	8·5	12·5	19·5	—	28	70
Elastic Modulus, $t.s.i. \times 10^3$	13·6	—	—	—	14·8	15·5	—	22·7
Curie Point, °C.	353	280	200	Non-Magnetic				

coincides very conveniently with the operating temperatures of oxide-coated cathodes. Most requirements will, however, be met by alloys containing up to 30 per cent. tungsten, and these are more readily manufactured than age-hardening alloys. For the construction of indirectly heated cathodes, where thin-walled tubes are employed, it is considered that the nickel-20 per cent. tungsten alloy will be the most suitable from the viewpoint of both technical and manufacturing requirements.

'This range of alloys may also find applications for other electrodes in vacuum tubes, where their high strength after high-temperature outgassing, their high electrical resistivities, and non-magnetic properties make them a useful addition to the limited number of metallic materials which may be used in valve construction.'

Effect of Neutron Irradiation on Precipitation Hardening in Nickel-Beryllium Alloys

R. H. KERNOHAN, D. S. BILLINGTON and A. B. LEWIS: 'Effect of Neutron Irradiation on the Precipitation-Hardening Reaction in Alloys containing Beryllium.' *Jnl. Applied Physics*, 1956, vol. 27, Jan., pp. 40–2.

Earlier investigations had indicated that neutron bombardment affected the course of precipitation hardening in a copper-base alloy containing beryllium.

In the work now reported a nickel alloy containing 2 per cent. of beryllium was selected for study, since, in addition to exhibiting precipitation-hardening characteristics similar to those of copper-beryllium alloys, the nickel-base material is ferromagnetic, and its Curie temperature has been shown to be a linear function of the amount of beryllium in solid solution. Such a relation of composition and properties makes it possible to determine, by Curie-temperature measurements before and after neutron bombardment, the extent to which such treatment influences precipitation. The Curie temperature of a specimen irradiated at a temperature of about 35°C. showed no change after irradiation (whereas in a copper-beryllium alloy similarly treated a pronounced change had been observed). In a nickel-beryllium alloy irradiated at 300°C., however, it was found that 1·3 at. per cent. more beryllium, in the form of the compound NiBe, had precipitated from solid solution than had precipitated in a similar specimen held at 300°C. but not irradiated.

Calculation of Gamma Radiation Induced in Reactor Materials

See abstract on p. 56.

Ferromagnetic Resonance in Nickel and Nickel Alloys

K. J. STANDLEY and K. H. REICH: 'Ferromagnetic Resonance in Nickel and in Some of its Alloys.' *Proc. Physical Soc., Sect. B*, 1955, vol. 68, Oct. 1, pp. 713–22.

Report on study of microwave absorption in nickel and in alloys of this metal with copper, aluminium, antimony and manganese. The object of the investigation was to examine the variation of the spectroscopic splitting factor g and the damping constant $1/T_2$ of the ferromagnetic metal in various degrees of dilution with non-ferromagnetic elements. The measurements were made on polycrystalline specimens, at a wavelength of 1·22 cm. and in the temperature range 20°–200°C. or to the Curie point, whichever was the lower temperature. The compositions of the alloys for which data are tabulated are shown below.

Nickel-copper alloys containing 0·8, 4·6, 9·75, 14·8, 24·7, 26·4 and 28·5 at. per cent. copper.

Nickel-aluminium alloys containing 5·1, 6·3 and 9·5 at. per cent. aluminium.

Nickel-antimony alloys containing 3·1 and 4·2 at. per cent. antimony.

Nickel-manganese alloys containing 1·2, 5·1, 10·1 and 13·5 at. per cent. manganese.

Nickel Alloys Showing High Secondary-Emission Characteristics

J. MILLET: 'New Nickel-Beryllium Alloy Showing Secondary Emission.' *Vide*, 1955, vol. 10, July-Sept., pp. 96–102.

This is a full account of work to which brief reference was made in *Comptes Rendus*, 1954, vol. 239, Oct. 4, pp. 794–6: see *Nickel Bulletin*, 1954, vol. 27, No. 12, p. 227. Binary nickel alloys containing beryllium up to 4 per cent. or magnesium up to 1·2 per cent. were investigated. The beryllium alloys, which are the main subject of this paper, showed considerably higher secondary emission than the magnesium-containing type. It is also recorded that production of the nickel-magnesium alloys presented some difficulties.

Nickel and Nickel Alloys for Pressure Vessels

R. M. WILSON and W. F. BURCHFIELD: 'Nickel and High-Nickel Alloys for Pressure Vessels.'
Welding Research Council Bulletin No. 24, Jan., 1956; 27 pp.
Abstract in *Welding Jnl.*, 1956, vol. 35, Jan., pp. 325–405.

Continuous advance in processing methods, involving higher temperatures and pressures, is resulting in a call for progressive improvement in materials used for pressure vessels. Problems of high strength, metal stability, and resistance to corrosion have in recent years assumed increasing importance, and in some industries stringent requirements with regard to purity of product add to the problem.

An important outcome of these changes is a growing demand for the use, for pressure-vessel construction, of materials having 'special' properties in respect of resistance to corrosion, high temperature, oxidation, etc. Nickel and a number of high-nickel alloys are among the materials which come into consideration in this field, and it is therefore important to have available, in ready reference form, comprehensive information on their properties. To this end, the Materials Division of the Pressure Vessel Research Committee of the Welding Research Council recently commissioned the preparation of an 'interpretive report' which would give data relevant to the application of nickel and nickel-base alloys in this type of service.

The materials covered are:—

Nickel, commercially pure (not more than 0·15 per cent. carbon).
This material is resistant to corrosion by fixed alkalis, and in some reducing acid conditions. It may be used at temperatures up to 600°F. (315°C.).

Low-Carbon Nickel (carbon not more than 0·02 per cent.).
This material may be used at all temperatures.

Monel, a high-nickel, nickel-copper alloy.
Used mainly in applications requiring strength and corrosion-resistance.

Inconel, a nickel-chromium-iron alloy.
Used primarily on account of its resistance to corrosion at elevated temperatures.

Hastelloy B, a nickel-molybdenum-iron alloy.
Shows good resistance to corrosion by hydrochloric acid, wet hydrogen-chloride gas, and sulphuric acid.

Hastelloy C, a nickel-molybdenum-chromium-iron-tungsten alloy.
Characterized by excellent resistance to strongly oxidizing acid conditions.

K Monel, a heat-treatable nickel-copper alloy containing aluminium.
Has the same corrosion-resisting characteristics as Monel, and after precipitation age-hardening treatment shows higher mechanical properties.

Inconel X, a nickel-chromium-iron-titanium-aluminium alloy.
Can be age-hardened to give high strength at elevated temperatures.

The first six of these materials are recognized by the A.S.M.E. Pressure Vessel Code. K Monel and Inconel X are not yet covered by the Code for general pressure-containing units, but it is anticipated that they will be included in the near future, as pressures and temperatures of processing rise.

All the materials mentioned can be fabricated by conventional methods, but they have certain characteristics which differ markedly from those of steels, and some modifications in processing methods are therefore necessary.

This report gives a detailed account of composition, physical and mechanical properties, basis for determining design stresses, susceptibility to embrittlement by sulphur and lead, and other characteristics of the high-nickel materials. Practical recommendations are made on cold forming, hot forming, thermal treatments, cleaning and pickling procedures, welding and brazing technique, and inspection. A special section of the report is devoted to the characteristics of age-hardenable alloys.

A large amount of practical information is presented: much of this is in tabular and graphical form, and illustrations of typical pressure vessels in nickel and high-nickel alloys are included.

Nickel Alloys in Hydrochloric-Acid Plant

See abstract on p. 74.

Galvanic-Couple Corrosion Data for Titanium

See abstract on p. 75.

Nickel-containing Coinage: Royal Mint Report

'Eighty-Fifth Annual Report of the Deputy Master and Comptroller of the Royal Mint for the Year 1954.'

Published by *Her Majesty's Stationery Office*, 1956; 84 pp. + index. Price 4/-.

In addition to the overall report of the activities of The Royal Mint, London, and its Branches in Melbourne and Perth, the volume includes memoranda by the Superintendent of the Operative Department and by the Chemist and Assayer of the Mint, and the usual statistics of silver, cupro-nickel and nickel-brass coins struck, issued, returned, held by banks, etc. Information on work done in connexion with medals and seals is also included. The verdicts of the jury at the Trial of the Pyx, as delivered on May 11, 1955, are recorded.

The report of the Chemist and Assayer gives results of continued work on the application, at the Royal Mint, of disodium ethylenediamine tetra-acetate (E.D.T.A.) in volumetric analysis. Methods employing this reagent in the estimation of nickel have been successfully applied to the determination of the nickel content of commercial nickel and of nickel in electro-plating baths. Murexide (ammonium purpurate) is used as an indicator, and as E.D.T.A. is very stable and non-toxic the methods have obvious advantages over the standard cyanide titration. Murexide gives an amber colour in the presence of nickel ions in strongly ammoniacal solutions, and the colour changes sharply to violet-blue when all the nickel is complexed with E.D.T.A. It is noted that the presence of large quantities of ammonium salts should be avoided, since these compounds render the end point less distinct. The report gives full details of procedure.

NICKEL-IRON ALLOYS

Constitution of Alloys: Bibliography

See abstract on p. 62.

Nickel and Nickel Alloys made by Powder Metallurgy

See abstract on p. 57.

Nickel-Alloy Magnets in Meters

H. WILKINSON: 'Alnico Magnets for New Meter.'

Canad. Metals, 1955, vol. 18, Oct., pp. 42-4, 46.

A recent outstanding development in Canada has been the production of a new watthour meter, which has been designed to give specially high accuracy and reliability, and to ensure long trouble-free service. Among more than one hundred components which go to the making of this meter, two damping magnets are of considerable importance and it is with these that the present article is concerned.

Production and processing operations, as carried out in the permanent-magnet foundry of the Canadian General Electric plant in Quebec City, are described: mould making, casting, heat-treatment, grinding, inspecting, testing and calibrating procedure is reviewed. The magnets are made from Alnico V alloy, for which the following composition is given:—aluminium 8, nickel 14, cobalt 24, copper 3, iron 51, per cent. Close control in sand-mould tolerances, insistence on purity of constituent elements, and heat-treatment in a magnetic field are factors of major importance in ensuring high and consistently reliable properties. Compliance with magnetic requirements of extreme stringency is ensured by a series of screening tests, details of which are given in this article.

Nickel and Nickel Alloys in Waveguide Devices

See abstract on p. 62.

CAST IRON

S.G. Iron: Properties and Uses

J. L. EVERHART: 'Nodular or Ductile Iron.'

Materials and Methods, 1955, vol. 42, Oct., pp. 119-34.

This review is one of a series of comprehensive articles prepared by the editors of this journal as special sections or 'Manuals', to provide reference data on the characteristics and uses of engineering materials, parts and finishes. This Manual, No. 120 in the series, discusses the overall development of S.G. iron and particularly its mechanical and physical properties, the heat-treatments applicable, and the main commercial applications.

Heat-Treatment of S.G. Iron

R. E. SAVAGE: 'Heat-Treating Ductile Iron.'

Steel, 1955, vol. 137, Nov. 21, pp. 108-9; Nov. 28, pp. 109, 112, 114, 115.

The author reviews the various types of heat-treatment which can be applied to S.G. iron castings. Properties quoted for the castings after treatment are in line with the data given in other recent papers. Nickel-molybdenum additions (e.g., nickel 1·0, molybdenum 0·5, per cent.) are advocated for castings required to show hardenability when either fully or locally heat-treated.

Machining and Grinding of S.G. Iron

INTERNATIONAL NICKEL CO., INC.: 'Machining and Grinding Ductile Iron.'

Publn. issued 1955; 16 pp.

Detailed recommendations are made on equipment and technique for machining and grinding of S.G. iron in various conditions.

Notch-Ductile High-Strength S.G. Irons

G. A. SANDOZ, H. F. BISHOP and W. S. PELLINI: 'Notch-Ductile High-Strength Nodular Irons.'

Trans. Amer. Soc. Metals, 1955, vol. 48, *Preprint* No. 21; 18 pp.

Conventional austenitization treatments of spheroidal-graphite cast irons develop high-carbon

austenites which preclude the possibility of obtaining ductile material by quenching and tempering. This limitation is due to the inherent brittleness of the high-carbon transformation products, but partial austenitization treatments, involving holding in inter-critical temperature ranges, control the carbon content of the austenite, and this paper reports a study of the combinations of tensile properties and notch ductility which may be obtained in various S.G. irons by controlled partial austenitization, water-quenching, and tempering at 1200°F. (650°C.).

The principal conclusions are as follows:—

'1. Ferritized nodular irons re-heated to temperatures in the range of 1400°-1550°F. (760°-845°C.) for periods of approximately four hours develop quasi-equilibrium austenite-ferrite aggregate structures.

'2. The amount of austenite developed at quasi-equilibrium increases with increasing temperature in the inter-critical range, and with decreasing silicon at any given inter-critical temperature. The austenitization changes are such as to permit practical control by means of guide charts.

'3. The partially austenitized nodular irons may be quenched and tempered to develop tensile strengths of the order of 90,000 p.s.i. (40 tons per sq. in.), with notch-ductility properties equivalent to the 60,000 p.s.i. (27 tons per sq. in.) ferritized material. The pearlitic nodular irons of 90,000 p.s.i. (40 tons per sq. in.) tensile strength show greatly inferior notch-ductility in comparison with the quenched-and-tempered irons.

'4. Heat-treatment to tensile strengths in excess of 100,000 p.s.i. (45 tons per sq. in.) results in an abrupt loss of notch-ductility. The higher-strength materials are inferior to the pearlitic 90,000 p.s.i. (40 tons per sq. in.) grades in this respect.

'5. The hardenability of unalloyed nodular irons is sufficient to develop the properties described in 1-in. plate sections and 2-in. rounds. At these limits, traces of pearlite are developed at the centre of the sections. These limits may be raised by alloying to increase hardenability.

'6. The presence of untransformed ferrite permits water-quenching without cracking or warping. In contrast, fully austenitized material is known to crack easily on water quenching.'

S.G. Iron Piping

M. GRANDPIERRE and C. C. REYNOLDS: 'Ductile Iron: A New Material for Petroleum Pipe.'

Amer. Petroleum Inst., Preprint, Nov. 14, 1955; 11 pp.

The authors describe the successful performance of S.G. iron piping to date, with particular reference to developments in Europe. The properties of the material are reviewed and many applications of piping are illustrated. It is emphasized that, with regard to bursting strength, shock-resistance, tensile strength and ductility, S.G. iron pipe is greatly superior to conventional, centrifugally-cast flake-graphite iron pipe, and that it equals steel in its ability to be safely bent in the field and to be laid, with relative ease, in long lengths in uneven terrain.

Special reference is made to the use of S.G. iron pipe for the following purposes:—

Re-Heater Coils in Oil Tankers. It is stated that some 25 tankers fitted with S.G. iron pipe are now in service, and that after three years the piping shows no appreciable deterioration.

High-Pressure Gas Mains. In this connexion particular reference is made to the pipeline now operating between Frontignan and Sete (France), which carries crude refinery gas over a distance of more than two miles. This piping passed a pressure test at 850 p.s.i.

The authors conclude that the unique combination of corrosion-resistance, yield strength and machinability, plus response to heat-treatment, and the well-known process advantages of S.G. iron, render it particularly suitable for pipelines handling oil and gas.

CONSTRUCTIONAL STEELS

Ultra-High-Strength Nickel-Alloy Steel for Airframes

J. DIETZ and L. H. McCREERY: 'High-Strength Steel: Application in Airframe Manufacture.'

Aircraft Production, 1956, vol. 18, Feb., pp. 74–7.

This paper is based on experience, in the works of Chance Vought Aircraft, Inc., in the use of nickel-chromium-molybdenum steel to S.A.E. 4340 specification,* heat-treated to tensile levels of 260,000–280,000 p.s.i. (116–125 tons per sq. in.). Design considerations which must be satisfied in order to ensure economic and safe application of the steels in this ultra-high-tensile condition are reviewed, and particular attention is drawn to the importance of correct heat-treatment. Properties typical of the steel in two conditions are shown in the table on page 68.

Emphasis is also laid on the precautions which must be observed if the steel is plated, e.g., with cadmium or chromium. (In this connexion a description is given of an embrittlement test developed by Chance Vought, Inc., for use on plated steel.)

Initially considerable difficulty was experienced in machining the steel in the ultra-high-tensile condition, but, as a result of extensive experiments, suitable technique has been developed. Detailed recommendations are given in this paper with regard to machining procedure and post-machining thermal treatment.

The combination of properties obtained in the wrought steel led to consideration of the possibility of developing a casting material of parallel type. A modified 4340 composition has been evolved and some acceptable shell-moulded castings have been produced: properties quoted as average for the cast material are as follows: yield strength 220,000 p.s.i. (98·5 tons per sq. in.), ultimate tensile strength 260,000 p.s.i. (116 tons per sq. in.), with elongation of 5 per cent. Such results have been considered sufficiently promising to warrant further investigation, which is now under way.

**Carbon 0·38–0·43, nickel 1·65–2·00, chromium 0·70–0·90, molybdenum 0·20–0·30, per cent.*

Average Mechanical Properties of Wrought 4340 Steel after Various Tempering Treatments

Tempering Treatment (after quenching to 95% martensitic structure)	U.T.S.		Yield Strength		Elongation	Reduction of Area
	p.s.i.	t.s.i.*	p.s.i.	t.s.i.*	% on 2 in.	%
400°F. (205°C.)	272,000	121·5	219,000	98·0	10	37
400°F. (205°C.) .. .. Soaked 200 hrs. at .. 400°F. (205°C.) ..	263,000	117·5	226,000	101·0	9	38

** To nearest half ton.*

See also—

J. DIETZ AND L. H. MCCREERY: 'Fabricating Ultra-High-Strength Steel.'

Product Engineering, 1955, vol. 26, Dec., pp. 170–3.

Reprint issued by *International Nickel Co., Inc.*, 1955.

Due to the higher tool costs involved and the closer control and inspection essential during manufacture, the cost of fabricating ultra-high-tensile steel parts is at present slightly greater than that involved in processing steels of lower tensile strength, but the reduction in weight made possible by the use of the stronger materials can more than offset the higher working costs. This paper makes practical recommendations on the heat-treatment, machining practice, designing, and plating of the nickel-chromium-molybdenum 4340-type steel in the ultra-high-tensile condition.

German Standard Alloy Steels

'German Alloy Steels.'

Automobile Engineer, 1956, vol. 46, Feb., pp. 55–8.

Review of compositions of heat-treatable and case-hardening steels currently used in Germany, and comparison with some British Standard types.

Welding of Carilloy Steel

H. S. DAVIS: 'How to Get Better Welds in a Weldable Steel.' *Iron Age*, 1956, vol. 177, Jan. 19, pp. 70–1.

Carilloy steel, specially developed as a plate material, has the following typical chemical composition: carbon 0·15, silicon 0·24, manganese 0·75, sulphur 0·030, phosphorus 0·026, nickel 0·85, chromium 0·50, molybdenum 0·45, vanadium 0·05, copper 0·31, boron 0·0029, per cent. Heat-treatment consists of water-quenching from 1650°F. (900°C.) and tempering at 1150°–1200°F. (620°–650°C.). Properties reported as typical of the steel in two plate thicknesses are given in the paper.

For welding this steel by the inert-gas-shielded metal-arc or Aircomatic process, a low-alloy steel wire of the following composition has been developed: carbon 0·08, silicon 0·50, manganese 1·22, sulphur 0·023, phosphorus 0·014, nickel 1·30, chromium 0·10, molybdenum 0·48, vanadium 0·14, per cent. For welded plate which must be heat-treated, wire of a somewhat modified type is preferred, *viz.*, carbon 0·08, silicon 0·40, manganese 1·15, sulphur 0·020, phosphorus 0·022, nickel 1·15, chromium 0·12, molybdenum 0·40, vanadium 0·17, per cent. Properties typical of welds are tabulated. When welding Carilloy steel with electrodes, a low-hydrogen-coated type is recommended, the exact nature of the electrode varying according to whether stress-relief treatment is to follow welding. Such treatment is not usually necessary, since the joints are tough in the as-welded condition, but it may be advisable in cases in which stress-corrosion attack may be involved in service, or in which dimensional stability during machining must be ensured. The stress-relief temperature should not exceed 1150°F. (620°C.).

It is noted that soundness of the weld metal can be affected by welding technique, surface condition of the wire used, and the welding current employed. Welds made with argon or helium as the protective gas tend to show more porosity than those made with an atmosphere of argon plus one per cent. of oxygen.

Difluorodichloromethane as Boundary Lubricant

S. F. MURRAY, R. L. JOHNSON and M. A. SWIKERT: 'Difluorodichloromethane as a Boundary Lubricant for Steel and Other Metals.'

Amer. Soc. Mechanical Engineers, Paper 55-LUB-2, 1955; 5 pp. + tables and figures.

A report published earlier in 1955 had suggested that fluorine- and chlorine-substituted methane and ethane derivatives be considered as possible high-temperature lubricants (N.A.C.A. Tech. Note 3402.) This paper describes experiments made to determine the ability of difluorodichloromethane to lubricate various metallic materials which are of interest as bearing surfaces in turbine engines. The tests were made in a kinetic-friction apparatus having a hemispherical specimen sliding on a rotating disc: this was operated in an atmosphere of difluorodichloromethane.

Results are summarized in the table on page 69.

It will be noted that difluorodichloromethane was most effective in lubricating steel surfaces when both

Rider Material*	Disk Material*	Relative Effectiveness of Lubricant	Condition of Surfaces (as compared with running in air)
Mild Steel (RA 50)	Mild Steel (RA 50)	Good	Wear and surface damage similar to results with liquid lubricants
High Carbon Steel (RC 60)	Mild Steel (RA 50)	Poor to fair	Some beneficial effect on wear and surface damage
Mild Steel (RA 50)	Tool Steel (RC 62)	Poor	Heavy wear of rider specimen
High Carbon Steel (RC 60)	Tool Steel (RC 62)	Good	Wear and surface damage similar to results with liquid lubricants
347 Stainless Steel (RA 51)	347 Stainless Steel (RA 51)	Poor	Severe surface damage and welding
Electrolytic Silver (RA 38)	Electrolytic Silver (RA 38)	Poor	Heavy wear and surface damage
Electrolytic Silver (RA 38)	Tool Steel (RC 62)	Poor to fair	Heavy wear of silver
Electroplated Lead Flash over Silver on Bronze	Tool Steel (RC 62)	Poor to fair	Plating quickly worn away; fairly heavy wear of bronze
Pure Copper (RA 41)	Mild Steel (RA 50)	Poor	Heavy wear of copper; considerable metal transfer to disk
Beryllium Copper (RA 36)	Tool Steel (RC 62)	Good	Effectively lubricated
Modified H-Monel (RA 63)	Tool Steel (RC 62)	Good	Effectively lubricated
Cast Inconel (RA 50)	Tool Steel (RC 62)	Poor to fair	Some beneficial effect on wear and surface damage

** Rockwell Hardness shown in brackets*

the surfaces were of similar hardness. Modified H Monel sliding on hardened tool steel was one of the combinations which proved most suitable for lubrication with this medium. The investigation showed that method and conditions of application of the lubricant are very critical when gaseous media are used, and that further research will be necessary before gaseous lubrication can be successfully applied on a practical basis.

Absorptiometric Determination of Nickel in Steel

See abstract on p. 60.

Calculation of Gamma Radiation Induced in Reactor Materials

See abstract on p. 56.

HEAT- AND CORROSION-RESISTING MATERIALS

Constitution of Alloys: Bibliography

See abstract on p. 62.

American High-Temperature Alloys: Composition and Properties

'Approximate Strength of Jet-Engine Alloys after Optimum Treatment.'

Metal Progress, 1956, vol. 69, Jan., p. 96B.

Tabular summary of tensile and stress-rupture properties, at various temperatures, of the following materials:—

Inconel X
Haynes Alloys 31, 25, 21
Waspaloy
M–252
S–816
N–155 Multimet
A–286 (modified Tinidur)
Discaloy
Refractaloy 26
Timken 16–25–6 Steel
Timken 17–22–AS Steel (Cyclops 14 MV)
A.I.S.I. Austenitic–Chromium–Nickel Steels Types 347 (Nb–stabilized) and 321 (Ti–stabilized).

Nickel Aluminides: Constitution and Properties

See abstract on p. 63.

Control of Quality in Production of Wrought Non-Ferrous Materials

See abstract on p. 63.

Chemical Polishing and Etching of Nimonic Alloys

E. MEACE: 'The Chemical Polishing and Etching of Certain Nimonic Alloys for Metallurgical Examination.' *Electroplating and Metal Finishing*, 1956, vol. 9, Feb., pp. 51–2.

This note describes experiments in the laboratory of Messrs. Joseph Lucas (Gas Turbine Equipment), Limited.

Routine metallurgical examination of heavy alloys usually involves careful hand polishing followed by electrolytic etching. The work described here was carried out in an attempt to develop procedure for chemical etching and smoothing to a condition suitable for micro-examination. The solutions with which tests were made are shown in the table below.

Before immersion in the solutions the specimens were activated by treatment with dilute sulphuric acid, and in the initial polishing experiments temperatures between 15° and 80°C. were used. The following comments are made on the results obtained:—

No. 1 solution failed to etch to any marked degree.

No. 2 solution caused pitting.

Dilution of No. 2 solution with water, glycerol and alkali salts (in order to obtain an intermediate composition) effected little improvement, but—

No. 3 solution produced a satisfactory etch, and it was found that glycerol could be used in place of phosphoric acid, with almost identical results.

No. 4 solution was one developed as specially suitable for etching welds in Nimonic 75.

For Nimonic 80A and Nimonic 90 neither solution No. 3 nor No. 4 proved satisfactory, but reduction of the hydrochloric acid content of No. 4 resulted in No. 5 solution, which gave good results for these two alloys, provided that different conditions of treatment were used: see table below.

In tests with solutions 3–5 inclusive preliminary activation with dilute sulphuric acid made no visible difference in the etch produced: this preliminary treatment was therefore discontinued.

The article is illustrated with typical photomicrographs showing the structural delineation obtained by the various treatments.

Pickling of Metals and Alloys

See abstract on p. 56.

Difluorodichloromethane as Boundary Lubricant

See abstract on p. 68.

Rolling of Stainless Steel from Powder

S. STORCHHEIM, J. NYLIN and B. SPRISSLER: 'Rolling 18–8 Stainless-Steel Powder into Strip.'
Sylvania Technologist, 1955, vol. 8, April, pp. 42–4.

A report of experiments in which the rolling of stainless-steel powder into strip form was studied as a function of a number of rolling and sintering variables. Graphs show, *inter alia*:—

(*a*) Density of green strip rolled from powder, as a function of roll opening.

(*b*) As-sintered density of rolled strip, as a function of (1) sintering temperature (1080°–1300°C.) and (2) time at 1200°C.

(*c*) Variation of as-sintered tensile strength of rolled strip with time at various temperatures, 1300°, 1200°, 1140° and 1080°C.

The results show, (see table on page 71), that it is possible to produce by this method strip showing high density, good tensile strength, satisfactory ductility, good corrosion-resistance and relatively random crystallographic orientation. The tensile strengths obtained were higher than those resulting from the use of conventional powder-metallurgical techniques of die compacting and sintering. The new method appears to be applicable to both soft and moderately hard metal powders.

Forming of Cermets by Low-Frequency Vibration

See abstract on p. 56.

Properties of Nickel-Tungsten Alloys Produced by Powder Metallurgy

See abstract on p. 63.

Solution No.	Acid Mixture (% by vol.)				Time (secs.)	Temp. °C.	Material
	HNO_3	HCl	Glycerin or H_3PO_4	CH_3COOH			
1	37	9	9	45	—	—	—
2	33	25	Nil	42	—	—	—
3	33	16	9	42	10	70	Nimonic 75
4	30	24	8	38	5	70	Nimonic 75 (Welded)
5	31	21	8	40	135	30	Nimonic 80A
				—	95	45	Nimonic 90

Comparison of Properties of 18-8 Stainless Steel Fabricated by Various Methods

Material	Ultimate Tensile Strength		Elongation
	p.s.i.	t.s.i.	%
Wrought 302 stainless steel, annealed ..	80,000—90,000	35·7—40·15	55—60
Die-pressed, sintered and coined powder-metallurgy specimens made from 302 stainless steel*	87,000	38·8	32
Re-rolled powder strip made from 302 stainless steel	108,000 (annealed after re-rolling)	48·2	33

* Specimens of −100 mesh powder cold pressed at 50 t.s.i., sintered at 1260°C. for 45 minutes, coined at 50 t.s.i. and re-sintered at 1250°C. for 45 minutes.

Mass Transfer of Nickel and Other Metals in Molten Lead

J. V. CATHCART and W. D. MANLY: 'The Mass Transfer Properties of Various Metals and Alloys in Liquid Lead.'

Corrosion, 1956, vol. 12, Feb., pp. 87t-91t.

The physical properties of liquid metals (high heat capacity, excellent thermal conductivity and generally low viscosity) render them ideal as heat-transfer media. Since they have relatively low vapour pressures, it is possible to use such materials at much higher temperatures than can be employed with the more conventional coolants such as steam, and a markedly increased efficiency of heat transfer is thus achieved. The mercury boiler, sodium-cooled valves, and various types of heat-treatment bath are outstanding examples of the commercial application of liquid metals.

Although the use of liquid metals has been to some extent limited by their corrosive effect, recent requirements for compact high-level power sources have created renewed interest in high-temperature heat-transfer media. In this connexion the phenomenon of 'mass transfer' has been the most serious practical obstacle. This term is used to indicate the solution of material from the hotter regions of a container, and its transport, by the flowing liquid metal, to the cold zone of the system, where the excess dissolved material is deposited. The deposit is frequently in the form of fine dendritic crystals, and, in a boiler or heat exchanger the pipes in the cooler regions soon become completely clogged by masses of interlocking crystallites.

The research described in this paper comprised a study of mass transfer suffered by a series of metals and alloys in liquid lead. The tests were made in small quartz thermal-convection loops: the temperature was about 800°C., with a thermal gradient of 300°C. existing across the loops. The types of material tested are shown below:—

Niobium; molybdenum; chromium and chromium-nickel stainless steels; chromium-silicon-iron alloy; nickel-molybdenum, nickel-molybdenum-iron and iron-molybdenum alloys; chromium-cobalt alloy; nickel-chromium-iron and chromium-iron alloys; beryllium, iron, chromium, cobalt, titanium, nickel; nickel-iron alloy, and nickel-chromium alloy.

Of the twenty-four materials tested, only molybdenum and niobium showed a high degree of resistance to mass transfer. The commonly used structural and alloying metals, such as iron, chromium and nickel, and their alloys, were much inferior in this respect, although some of the alloys exhibited a greater resistance than could be predicted from the properties of their component metals. The behaviour of some of the materials was correlated with the tendency to formation of intermetallic compounds in the alloys. Tests on pre-oxidized specimens indicated that the presence of a relatively heavy oxide film retards mass transfer, but it is recognized that such an effect is of little practical value. In addition to the barrier to heat transfer which would be set up by these films (e.g., in a heat exchanger), it is considered doubtful whether a crack-free oxide coating could be maintained in such a system under the erosive action of a flowing liquid metal or under the thermal strains produced by the temperature gradients present.

Resistance of Nickel-containing Materials to Sulphur Dew-Point Corrosion in Exhaust Gases

R. L. COIT: 'Sulphur-Dew-Point Corrosion in Exhaust Gases.'

Trans. Amer. Soc. Mechanical Engineers, 1956, vol. 78, Jan., pp. 89-94.

Sulphur dew-point corrosion continues to be an important problem in steam-power stations and in waste-heat recovery devices for gas turbines. The flue gases from steam generators or gas turbines usually have a calculated water dew point of about 100°F. (37°C.), and the surfaces of the various heat-recovery components are normally arranged so that the temperatures of the metals are well above the calculated dew point of the exhaust gases, thus preventing condensation of moisture. In many cases, however, it is found that part of the sulphur in the fuel leaves the combustion zone not as sulphur dioxide but as sulphur trioxide. (The possible mechanism of formation of the SO_3 is briefly considered.) After the sulphur

has been oxidized to SO_3 a gas-phase reaction occurs at a temperature well above the dew point and the SO_3 combines with water to form H_2SO_4. Although the percentage of sulphur in the fuel is small, and the proportion of this sulphur which is oxidized to sulphur trioxide is also small, it may be sufficient to raise the dew point by as much as 250°F. (140°C.). The dew point of the exhaust gases may then be as high as 350°F. (177°C.) and it may not be economically feasible to maintain all the metal temperatures above the dew point. Condensation of sulphuric acid occurs on the cool surfaces, and intensive corrosion results.

The authors of this paper briefly review the literature relevant to the effect of sulphuric acid on the dew point of exhaust gases, and on dew-point corrosion, and report in detail the results of tests made with a view to finding materials of construction which would be resistant to corrosion and erosion in the conditions obtaining in compressors, valves, and heat exchangers in contact with sulphur-bearing exhaust gases. Preliminary screening tests were made by static and intermittent immersion tests in sulphuric-acid solutions of various concentrations, and the materials showing the most satisfactory resistance under such conditions were subjected to simulated-service tests. The complete series of materials used is shown in the table below.

The conclusions drawn from the tests are summarized as follows:—

'Static-exposure tests indicated that while N-155, Type 310, and Type 304 stainless steels were satisfactory for use in sulphuric-acid concentrations of less than 0·8 per cent., they suffered rapid attack when exposed to a 50 per cent. solution of H_2SO_4. In these tests Hastelloy C appeared to be the most resistant of the alloys.

'A phenolic resin used in industry to coat acid containers appeared to be the most suitable coating to protect copper from acid attack. This coating was, however, badly attacked in a semiclosed-cycle test heat exchanger when a 1 per cent. sulphur fuel was used. Thus, it is indicated that no suitable coating is yet available to protect heat-exchanger surface materials from corrosion when high-sulphur fuels are used. Tests with very-low-sulphur fuel (0·005 per cent. S) showed a marked reduction in corrosion attack.

'In a series of rotating tests simulating compressor-inlet conditions, it was found that Type 316 stainless steel, Inconel, Carpenter No. 20, and Discaloy had high corrosion-resistance, while 12 per cent. chromium steel, Corten, Mayari-R, aluminium bronze and aluminium-nickel bronze showed high rates of corrosion.

'In low-temperature, moderate gas-velocity regions such as are found in precoolers, intercoolers, and waste-heat-recovery units, Type 316 stainless steel and Hastelloy C appeared to have good acid-resistance.

'A promising scheme for minimizing low-temperature corrosion in semiclosed cycles for gas turbines is to use direct-contact coolers (spray cooling) to replace surface types of precoolers and intercoolers.'

Material	C %	Mn %	Cr %	Ni %	Cu %	Fe %	Other Elements
Aluminium Bronze	—	—	—	—	95	—	5 Al
Aluminium-Nickel Bronze..	—	—	—	5	82	2·5	9·5 Al
Carpenter No. 20	0·07	0·75	20	29	3	44·2	2 Mo
Corten	0·1	0·4	0·9	0·45	0·4	97	—
Discaloy	—	—	13·5	26	—	54	1·6 Ti
Hastelloy B	0·1	1·0	1·0	63·5	—	—	28 Mo
Hastelloy C	0·15	1·0	16·5	54	—	—	17 Mo, 4 W
Inconel	0·08	0·25	14	78·7	—	6·5	—
Mayari-R	0·1	0·65	0·6	0·4	—	—	—
12% Chromium Steel ..	0·04	0·5	12·7	0·12	—	86·2	—
70–30 Copper–Nickel ..	—	—	—	30	69	—	1 Sn
Nickel–Chromium Stainless Steels—							
Type 304	0·05	1·5	19	10	—	68	—
Type 310	0·2	1·5	25	20	—	52	—
Type 316	0·05	1·5	19	12	—	65	—

Corrosion of Stainless Steel by Fuming Nitric Acid

J. D. CLARK and M. E. WALSH: 'The Corrosivity of Fuming Nitric Acid.'

Trans. New York Acad. Sciences, Ser. II., 1955, vol. 17, Feb., pp. 279–88.

Fuming nitric acid is an oxidizer which is frequently used for rocket fuels on account of its high percentage of available oxygen, its high density (which allows a large quantity of oxidant to be carried in a relatively small tank), and its low cost and ready availability. It is used either as white fuming nitric acid, which contains no more than 2 per cent. of water, and may contain as much as 2 per cent. NO_2, or as red fuming acid, which usually has a water content of 2–3 per cent. and may contain up to 25 per cent. NO_2.

Corrosion problems involved in handling these acids are widely different from those encountered in contact with the 'concentrated' 70 per cent. acid used in laboratory work. Whereas the 70 per cent. acid can be held indefinitely in containers of chromium-nickel stainless steels, the white fuming or red fuming acid, after a week or more in such containers is black with corrosion product.

The research reported in this paper was carried out by the Chemistry Branch of the U.S. Naval Air Rocket Test Station, with a view to determining the nature and rate of the attack, and possible means for reducing corrosion to a tolerable amount. Two series of tests were made:—

(1) with nitric acid containing 23% NO_2 and 2% H_2O, at 3°, 20° and 60°C.

(2) with nitric acids of various compositions, containing, initially, 0, 2·5, or 5% H_2O and 0 or 10% NO_2.

The steel used was niobium-stabilized '18–8'.

The red-acid tests were made in Teflon-lined stainless-steel bombs, pressurized with 25 p.s.i.g. of oxygen, in order to inhibit the autodecomposition of the acid. Both liquid- and gas-phase corrosion were measured. The runs made with the varying acids were conducted in glass containers, at atmospheric pressure: only liquid-phase corrosion was determined. Duration of tests: 35–260 days, depending on the rate of corrosion, which was determined by periodic removal of the specimens, washing, drying, and weighing.

From the results of the respective series of tests, which are individually reported, attention is particularly directed to the following points:—

(1) the general similarity of the corrosion-time curves when corrosion had progressed to any considerable degree,

(2) the magnitude of the inhibitory effect of water upon corrosion. For example, in 59 days acid containing no water corroded by about 485 mg./sq. in., whereas in 260 days acid containing 2·5 per cent. of water corroded by only 263 mg./sq. in., and acid containing 5 per cent. of water lost only 16 mg./sq. in.

(3) the inhibitory effect of NO_2 increases with increase in water content.

Tests on specimens in various surface conditions demonstrated that roughening of the metal, increasing its initial surface, shortens the corrosion-induction period, but has little effect on final rate of corrosion.

Consideration of the corrosion of this steel in nitric acid, in the light of these tests and other available data, leads the authors to the conclusion that the mechanism is as follows:—

$$2\,\overset{+}{N}O_2 + Fe \rightarrow \overset{++}{Fe} + N_2O_4$$

The rate can be described by the equation:—

$$R = a\,(\overset{+}{N}O_2)^{\frac{4}{3}}\; e^{-\frac{\Delta h}{RT}}$$

The constants a and Δh were determined.

Corrosion of Chromium-Nickel Stainless Steel in Ferric-Chloride Solutions

H. A. LIEBHAFSKY and A. E. NEWKIRK: 'Corrosion of Stainless Steel in Ferric-Chloride Solution.'

Corrosion, 1956, vol. 12, Feb., pp. 92t–8t; disc., p. 98t.

During radiographic examination of the pitting of 18–8 chromium-nickel stainless steels in ferric-chloride solution it was noticed that a large amount of metal could be dissolved without much change of appearance in the immersed specimen. The observations made led to the conclusion that the corrosion involved rapid and extensive internal removal of metal, initiated by relatively few pits, influenced by gravity, and accomplished through many small openings in surfaces which, when examined by reflected light, appear virtually intact. The experiments reported in this paper were made to study the mechanism of corrosion more closely.

Measurements of rate of weight loss in various specimens (in conditions which are described and illustrated in the paper) showed that the rate is closely similar in different samples. In most cases four stages are clearly recognizable: (1) a short induction period, (2) a stage of fairly constant, slow rate, which gradually changes into (3) a stage of rapid loss and, finally, when less than 2 per cent. of the specimen remains, into (4) a stage during which the rate is negligible. If, however, one side of a specimen was covered with gold (coating done by evaporation) these distinct stages were not observed; corrosion attack was rapid at the outset and the rate of attack gradually decreased. The implications of the observations made are discussed, and extension of the work, with a view to further elucidation of the mechanism of corrosion, is forecast.

Handbook on Nickel-Chromium Stainless Steels

F. H. KEATING: 'Chromium-Nickel Austenitic Steels.' Published by *Butterworths Scientific Publications*, in association with *Imperial Chemical Industries, Ltd., London*, 1956; 138 pp. Price 25/-.

This Handbook, which is one of a series issued by

Imperial Chemical Industries, on various technical subjects, is written primarily for the user, and as a reference book for the practical man. Although this aspect is emphasized, sufficient theoretical matter has been included to give the background necessary for full appreciation of application potential: producing and fabricating processes are discussed as affecting the properties and usability of the steels.

In accordance with this plan, the first chapter of the book contains a discussion of the austenitic condition, and factors of composition which influence austenite stability, and chapter 2 comprises a review of development of the chromium-nickel austenitic steels, including discussion of the nature of intercrystalline disintegration, the theory of grain-boundary attack, and steels which have been developed to obviate disintegration by intercrystalline breakdown. Chapter 3 is concerned with manufacturing and fabricating processes (melting and casting, hot and cold working, descaling, machining, grinding and polishing, riveting, and welding). Chapter 4 is devoted to cast austenitic steels, giving details of composition, treatment and properties, and brief reference to new methods of casting which are being applied to such materials. Chapter 5 contains a summary of mechanical properties typical of the respective grades of wrought austenitic chromium-nickel steels: data for normal, elevated and sub-zero temperatures are given, and information on physical properties is also tabulated. In chapter 6 the important aspect of corrosion-resistance is considered: the basis of the corrosion-resisting characteristics of these steels is discussed and metallurgical factors which affect resistance to corrosive attack are reviewed. Typical corrosion-test data are recorded, to illustrate the usefulness of the chromium-nickel steels under given conditions and, conversely, their susceptibility to attack under other conditions: the use of inhibitors is considered, and specialized forms of corrosive attack are described, e.g., pitting, deposit and crevice attack, contact (galvanic) corrosion, and stress corrosion. Some comments are made also on the use of the austenitic steels in conditions calling for resistance to oxidation or to abrasion. An appendix to this chapter contains a tabular qualitative survey of the behaviour of 18-8 Ti, 18-10-Mo-Ti and 18-18-Mo-Cu-Ti to a large number of corrosive reagents.

The analytical procedures described in chapter 7 are methods which have been built up from a variety of sources (British Standard methods, techniques recommended by the British Iron and Steel Research Association, published literature, and work in the I.C.I. laboratories). In the final chapter specifications for austenitic chromium-nickel steels are briefly considered. A *bibliography* of 58 items supports the text.

Although avowedly limited within the scope indicated in the preface, the Handbook is probably the only one which approaches the subject from exactly the practical-user angle indicated, and it should prove most useful for reference purposes.

Nickel and Nickel Alloys in Petrochemical Plant

R. L. DAVIDSON: 'Alloys in Your Plant Can Give You Product Purity, Physical Strength, Corrosion Protection, Erosion-Resistance.'
Petroleum Processing, 1955, vol. 10, Sept., pp. 1393–5.

This article contains a review of some of the applications for which nickel and its alloys have proved suitable in various types of equipment employed in branches of the petrochemical industry. These include heat-resisting nickel-chromium steel furnace tubes used in pyrolysis of ethane or propane, to form ethylene; supported nickel catalyst, packed in high-nickel alloy tubes, in production of synthetic gas by steam re-forming of natural gas; nickel tubes in polyvinyl-chloride plastics manufacture, where contamination of the product by copper, iron and other metals must be rigidly excluded; hardened nickel dies for forming plastic filaments; high-nickel materials in piping and other components of plant for chlorination, fluorination and other processes; nickel and nickel-clad steel in processing of phenol, where iron or other contamination would be highly detrimental to the final product, e.g., phenol formaldehyde resins, pharmaceuticals, etc.; nickel, high-nickel cast iron, and nickel-chromium stainless steels in equipment used in various stages of the manufacture of tetraethyl lead; high-nickel nickel-copper alloys and other corrosion-resisting materials in production of detergents; nickel and high-nickel alloys in plant producing synthetic glycerine.

Nickel Alloys in Hydrochloric-Acid Plant

'Hydrochloric-Acid Plant Makes Water-White Product.' *Chemical Processing*, 1956, vol. 2, Feb., pp. 4–5.

Description, with drawing, of some of the outstanding features of the plant of Messrs. F. W. Berk and Company, Ltd., at Stratford, London. Selection of materials resistant to the various forms of corrosive attack encountered in operation is an important aspect, and in this article reference is made to several parts made from alloys of specially selected types. For example, the salt, which is initially in a store having a concrete floor and timber-lined walls, is blown by hot air through a stainless-steel duct to a feed hopper which is made of pitch pine and lined with Monel, to prevent the salt from sticking to the wood.

In the furnace, to which carefully controlled amounts of salt (from the hopper) and sulphuric acid (from a concrete tank) are led, the lining is of firebrick, and inside the furnace is a large boss with four arms, each bearing two rabbles so placed as to ensure that all the saltcake is effectively ploughed and slowly pushed to the drop hole. Operating conditions are extremely severe, involving the combined corrosive effect of sulphuric acid, hydrogen-chloride gas, heat, and the erosive effect of the salt. Much difficulty was formerly caused by rapid deterioration of the rabbles, with resultant need for shut-down and replacement, but the adoption of Cronite, a high-nickel nickel-chromium-iron heat-resisting alloy, for these parts, has resulted in trouble-free operation for long periods. Further successful applications of

the same alloy include the revolving pot into which the sulphuric acid runs for distribution over the salt. Corronel B, a nickel-molybdenum-base acid-resisting alloy, also finds use in the Berk plant.

Galvanic-Couple Corrosion Data for Titanium

'Galvanic-Couple Corrosion Data for Titanium with Other Metals.' *Machine Design*, 1956, vol. 28, Jan. 26, p. 75.

In using titanium in conjunction with other structural engineering materials both may be subjected to corrosion by sea water or sea air. Tests have shown that the effect of titanium on other metals which are coupled to it is very similar to that exerted by stainless steel. Results shown in the table below indicate that stainless steel may be coupled with titanium without causing increase in the corrosion of either material, but that magnesium, aluminium and copper-base alloys should be insulated from titanium.

Corrosion Rate of Metals Coupled with Titanium*

Material	Sea Water %	Sea Air %
Magnesium, AZ31	150	400
Aluminium, Alclad 2024S-T3	300	500
Aluminium, 5052S, ½-hard ..	1000	100
Aluminium, Alclad 7075S-T6	500	750
Copper	350	300
Steel (low-carbon)	150	—
Monel	180	200
Inconel	100	100
Stainless Steel, Type 302 ..	100	100
Stainless Steel, Type 316 ..	100	100
Silver	170	—

* Normal corrosion of the metal by itself is given as 100 per cent.

Nickel and Nickel Alloys for Pressure Vessels

See abstract on p. 65.

Ultrasonic Testing of Stainless-Steel Tubing

W. L. FLEISCHMANN and H. A. F. ROCHA: 'Ultrasonic Testing of Small-Diameter Tubing with Automatic Recording Equipment.'

Trans. Amer. Soc. Mechanical Engineers, 1956, vol. 78, Jan., pp. 211–15; disc., pp. 215–16.

Until recently inspection of piping for high-pressure, high-temperature steam plant consisted in subjecting the exterior surfaces to visual examination, and, when specified, to a magnetic-particle or penetrant-oil test: the inside surface was examined by visual inspection of the illuminated bore. Although in many cases piping thus tested proved sound and gave good service, a failure in a power station, which was traced to a defect present before fabrication, led to introduction of ultrasonic testing. Procedure developed for inspection of such heavy-wall piping was reported by Moriarty in 1951 (*ibid.*, vol. 73, pp. 225–35).

The authors of this later paper describe progress which has been made, since that date, in ultrasonic test equipment. Automatic testing of small-diameter tubing now appears to be a likely development of considerable value to engineers, particularly those engaged in steam-plant and atomic-power plant construction. In demonstration of the information which can be obtained by ultrasonic testing, particulars are given of the type and size of discontinuities detected with such equipment in niobium-stabilized austenitic chromium-nickel steel tubing.

A warning is given with regard to difficulties involved in judging the severity of defects solely on the basis of amplitude indications: the importance of extensive experience in interpreting results is emphasized.

Properties of Modified Austenitic-Steel Weld Metal

R. D. THOMAS and L. K. POOLE: 'Mechanical Properties of Modified Type 347 Weld Metals.'

Welding Jnl., 1955, vol. 34, Dec., pp. 583S–95S.

Niobium-stabilized 19–9 chromium-nickel steel is of particular interest in connexion with atomic-energy plant, and this report has been prepared by the Advisory Committee of the Welding Research Council at the request of the Atomic Energy Commission on Stainless Steels, which is sponsoring a programme directed to the development of improved weld-metal compositions.

Work done prior to the establishment of this project had indicated some hope of developing a satisfactory fully austenitic weld composition, provided that certain of the elements present were controlled within narrow limits. Full evaluation tests had not, however, been made with electrodes of the types proposed, and the chief aim of the investigation now reported was therefore to determine the ability of these or other fully austenitic compositions to resist cracking and embrittlement, and to ascertain their suitability for service in corrosive media or in applications requiring strength at high temperatures. The portion of the research now reported comprised (*a*) tests designed to evaluate the ability of modified electrodes to meet standard fabrication codes, and (*b*) determination of tensile and impact properties of deposited weld metal, before and after exposure at elevated temperatures.

Table I (p. 76) gives details of composition of the electrodes and base metals used.

Type 'A' electrode was representative of standard Type 347 electrode composition, with 0·10 max. per cent. tantalum; type 'D' was an electrode of similar type, but manufactured with ferrotantalum-niobium and not having the requirement for the tantalum minimum specified for regular type 347

Table I

Composition and Designation of Electrode Weld Deposits*

Electrode	Type	C %	Mn %	P %	S %	Si %	Ni %	Cr %	Nb %	Ta %	N_2 %	Ferrite (calcd.†)
A	19/9 Nb	0·08	1·55	0·017	0·012	0·44	9·31	19·22	0·71	<0·03	0·044	7%
B	19/13 Nb	0·087	1·49	0·017	0·013	0·33	13·02	19·09	0·74	<0·03	0·039	None
C	19/13 Nb	0·115	1·32	0·019	0·013	0·45	13·06	19·09	0·70	<0·03	0·044	None
D	19/9 NbTa	0·080	1·55	0·017	0·010	0·42	9·27	19·22	0·64	0·14	0·039	7%
F	19/10 LC	0·036	0·73	0·021	0·018	0·26	10·53	18·92	—	—	0·044	4%
H	19/13 MnNb	0·095	5·04	0·024	0·012	0·37	12·99	18·50	0·91	<0·03	0·037	None

Composition of Core Wires

Alloy No.	Electrodes	C %	Mn %	P %	S %	Si %	Ni %	Cr %	Mo %	Cu %	N_2 %
E2846T308	A & D	0·066	1·57	0·014	0·012	0·39	9·50	19·75	0·02	0·05	0·022
E2842T309	B, C & H	0·063	1·59	0·013	0·010	0·35	13·24	19·60	0·02	0·05	0·019
E2847T308L	F	0·027	1·53	0·012	0·015	0·40	10·33	19·90	0·02	0·06	0·019

Composition of Stainless Steel Base Metals‡

For use in	Size	Type	C %	Mn %	P %	S %	Si %	Ni %	Cr %	Nb+Ta %
Fissure & Impact tests	½ in. × 3 in.	347	0·06	1·39	0·026	0·010	0·66	10·51	19·40	0·77
		304L	0·024	1·55	0·026	0·016	0·38	9·50	17·76	—
Fillet-weld tests	¼ in. × 2 in.	347	0·07	1·84	0·030	0·014	0·70	11·00	18·56	0·85
Butt-weld tests	1 in. × 4 in.	347	0·07	1·60	0·030	0·021	0·62	10·74	17·92	0·84
		304L	0·026	0·66	0·019	0·012	0·65	8·43	19·01	—
Pipe-weld tests	8 in. diam. × 1 in. wall	347	0·059	1·37	0·024	0·013	0·46	10·39	17·55	0·60
Backup strips	¼ in. × 1 in.	347	0·07	1·84	0·030	0·014	0·70	11·00	18·56	0·85
		304L	0·026	0·66	0·019	0·012	0·65	8·43	19·01	—

* Chemical analysis from non-dilution weld pads made in accordance with A.S.T.M.-A.W.S. specifications.
† Calculated from chemical composition according to Schaeffler diagram.
‡ Mill reports.

electrodes. Both 'A' and 'D' electrodes were designed to give about 7 per cent. of ferrite in the weld structure. Electrode 'B' is typical of a specially low-carbon, low-silicon composition: electrode 'C' contains higher percentages of both elements. Electrode 'H' is a high-manganese type. (In order to avoid delta ferrite in the as-welded structure, the nickel content in 'B', 'C' and 'H' compositions was raised from the normal 9–11 per cent. level to about 13 per cent.) The remaining composition, 'F', was intended to evaluate a non-niobium type which, due to its extremely low carbon content, would be presumed to be free from intergranular-carbide precipitation. The weld deposit from such an electrode would contain ferrite of the order of 4 per cent. The covering on all the electrodes except the E.L.C. type was a commercial grade, 'pure' lime type, i.e., substantially free from titanium dioxide. Preliminary work had indicated that this type of covering had the greatest ability to resist cracking. For the E.L.C. electrode such a covering was not feasible due to risk of carbon pick-up: a commercial lime-titania covering was therefore used, resulting in a carbon content, in the weld metal, well within the limits prescribed for commercial electrodes of this grade.

Four sets of tests were used for evaluation of fabricating characteristics: the methods were typical of those used commercially. Details are given of apparatus and technique employed in (*a*) the fissure test, (*b*) the fillet-weld test, (*c*) the butt-weld test, and (4) the pipe-weld test.

To evaluate the properties of the weld-metal deposits, duplicate tensile tests were made on specimens in each group, in the following conditions:—

(*a*) as-welded.
(*b*) heated for 8 or 100 hours at 1100°F. (595°C.)
(*c*) „ „ 8 „ 100 „ „ 1300°F. (705°C.)
(*d*) „ „ 8 „ 100 „ „ 1550°F. (840°C.)
(*e*) „ „ 8 „ 100 „ „ 1700°C. (925°C.)
(*f*) „ „ 2, 8 or 24 hours at 1950°F. (1065°C.)

In order to eliminate as far as possible the effect of heating and cooling rates (which have been reported to affect mechanical properties), the heat-treatments were made as nearly isothermal as possible.

Results of the tensile tests are shown graphically.

A further section of the investigation comprised notched-bar impact tests, to assess embrittlement after exposure to elevated temperatures (during service or in post-weld heat-treatment), and to evaluate the suitability of the respective electrodes for use in welds used in sub-zero applications. The as-welded and heat-treated conditions in which the specimens were tested were similar to those in which the tensile specimens were examined: see above.

Conclusions

The following notes summarize the main conclusions drawn from the results of the various series of tests:

With the exception of 'B' type, all the electrodes may be considered suitable for production welding and for fabricating structures to withstand stress and impact conditions normally encountered by austenitic steel weldments. Some electrodes are, however, more limited in application than others: such differences are discussed below.

Composition 'A'. Due to the 7 per cent. average ferrite content, in the as-welded condition, the welds are highly resistant to cracks and fissures, but on prolonged exposure at 1000°-1700°F. (540°-925°C.) the ferrite transforms to sigma, causing notch brittleness, increase in tensile strength and loss in ductility. This electrode is recommended as the most suitable of the niobium-bearing types from the point of view of facility in fabricating crack- and fissure-free weldments under restraint. Mechanical properties are excellent in the as-welded condition. If post-weld treatment is required it should be at a temperature not below 1700°F. (925°C.) and it is desirable to specify a minimum time in the range 1100°-1700°F. (595°-925°C.). For welds which will be exposed at temperatures at which ferrite transforms to sigma, a prior annealing at 1950°F. (1065°C.) will dissolve and spheroidize the ferrite, thus minimizing embrittlement. If a niobium-stabilized composition is required for low-temperature service (e.g., −300°F.: −185°C.), type 'A' electrodes are suitable, provided that post-weld heat-treatment at 1700°F. (925°C.) is ensured.

Composition 'B'. This fully austenitic composition is not considered to be commercially feasible. Despite the very low carbon and silicon contents, it gave the poorest performance with respect to cracks and fissures in fabrication tests, and by comparison with the other fully austenitic electrodes ('C' and 'H') it shows no advantages in mechanical properties.

Composition 'C'. As gauged by fabricating tests, this was one of the two best fully austenitic compositions. Where a ferrite-free weld metal is essential and high carbon (up to 0·12 per cent.) is not objectionable, such electrodes might be considered.

Composition 'D'. Results demonstrate that tantalum can be substituted for part of the niobium without altering the mechanical properties of the weld. Comments made with regard to 'A' electrodes therefore apply also to 'D' type.

Composition 'F'. From the standpoint of ease of fabrication this electrode differs from all the others, due to the titania content of its coating: some difficulties were encountered in vertical welding and with slag entrapment, but the electrode is nevertheless considered satisfactory for commercial use. Chief characteristics resulting from its use are high ductility and toughness, even after prolonged exposure to elevated temperatures, and it is especially suitable for use in low-temperature service. Room-temperature strength is substantially below that of the niobium-bearing compositions, but equal to that of the wrought E.L.C. parent metal with which such an electrode would normally be used.

Composition 'H'. This high-manganese fully austenitic composition is very similar to 'C' in mechanical properties, and in cracking and fissuring characteristics. If a ferrite-free weld composition is required and carbon must be limited, the introduction of 5 per cent. of manganese appears to be suitable to control fissuring. Crater cracks may, however, be expected to a greater degree than when using partially ferritic compositions. The absence of ferrite makes the high-manganese electrodes suitable for application in parts which will be exposed to elevated temperatures and in which sigma formation must be minimized. The 'H' electrode, in common with other niobium-bearing fully austenitic grades, is not, in any condition of heat-treatment, suitable for sub-zero service.

It is noted that a programme of tests to evaluate the corrosion-resistance of the weld metals examined is under way.

Welding of Austenitic Steel Piping and Tubing

AMER. WELDING SOC.: 'The Welding of Austenitic Chromium-Nickel Steel Piping and Tubing. A Committee Report (Tentative).'
A.W.S. Publn. D10. 4-55T; 27 pp. Price $1.

Although many thousands of welded joints in austenitic stainless-steel piping assemblies have been satisfactorily fabricated and have given good service,

several problems have recently arisen in this connexion. These are mainly cracking, corrosion, and embrittlement at elevated temperatures: a particular difficulty is the occurrence of cracking in welded joints in niobium-stabilized '18-8'-type steels in service in steam-power generating stations operating at 1050°F. (565°C.). This matter is under intensive study, but no firm recommendations can yet be made.

The publication now issued by the American Welding Society has been prepared to give an overall view of (1) problems likely to occur in welded joints of austenitic steel pipe and tube, (2) welding technique which has proved suitable for such materials, and (3) inspection methods currently employed to assess quality of welds.

Section I includes a discussion of the occurrence of cracking, its cause, and the nature of the defect; the corrosion-resistance of welds (intergranular corrosion, stress corrosion, crater corrosion and galvanic corrosion); formation of sigma phase, in relation to balancing of austenite and ferrite contents of weld metal.

Section II deals with the suitability of the various grades of austenitic chromium-nickel steel for welded piping. Compositions normally used for this purpose are tabulated and a list is given of A.S.T.M. specifications to which they conform. Electrodes suitable for use with the respective steels are discussed, also the composition and structure of the weld metals produced.

Section III reviews the welding processes employed for joining stainless-steel pipe and tube. Of these, the most generally used are shielded metal-arc welding and inert-gas metal-arc welding with non-consumable electrodes. Inert-gas metal-arc (consumable-electrode) welding, which is used to a lesser extent, and submerged-arc welding, which is limited in its application, are also considered. It is noted that whilst the oxy-acetylene and atomic-hydrogen welding processes have been used for this purpose in the past, they are now employed to only a very limited extent.

Section IV gives details of filler metals, covered and bare.

Section V is concerned with welded pipe joints, including consideration of joint design, preparation, backing, etc.

Section VI contains practical recommendations on various aspects of welding technique. These include precautions necessary in starting the arc, operating position and handling of electrodes, weld size and contour, speed of travel, welding current, means of avoiding damage to the surface in stopping the arc, conditions in which peening may be useful or should be avoided, cleaning and finishing processes, and repair of unsatisfactory joints.

Section VII reviews inspection methods used to determine weld quality: the applicability and relative usefulness of the following methods are considered:— visual inspection, hydrostatic testing, liquid-penetrant methods, radiography, ultrasonic methods, inspection with a magnet, spot testing, the ammonia-phenol phthalein method, halide leak-testing methods, and the mass-spectrometer testing method.

At the end of the publication a list is given of A.W.S. Standards and other relevant publications issued by the Society.

Hot Cracking in Austenitic Steel Welds

P. P. PUZAK, W. R. APBLETT and W. S. PELLINI: 'Hot Cracking of Stainless-Steel Weldments.'
Welding Jnl., 1956, vol. 35, Jan., pp. 9s - 17s.

It is being increasingly recognized that the weldability of stainless steels is a critical factor in the development of high-temperature power plants. The niobium-stabilized 19-9 chromium-nickel grade, which is suitable for a wide range of chemical-engineering applications, is of particular interest in this connexion, since although in the form of thin sheet this steel can usually be welded without difficulty, considerable trouble has been encountered with cracking of welded castings or heavy forgings. This paper is a contribution towards the study of weld cracking in this type of steel.

Cracking may occur either:—

(1) Immediately after welding:—
- (*a*) in the form of base-metal cracks perpendicular to the weld;
- (*b*) transverse weld-metal cracks;
- (*c*) combinations of the above, with the base- and weld-metal cracks joining to form a continuous crack;
- (*d*) longitudinal cracking of the weld metal;
- (*e*) longitudinal cracking of the heat-affected zone.

(2) After heat-treatment.
Extensive cracking of weld and base-metal regions may be developed during or after stress-relieving or full heat-treatment of welded assemblies.

Earlier work had led to the conclusion that development of hot cracks in welds depends on the same factors which affect hot tearing in castings; this similarity is discussed at some length by the authors, and the cracking occurring in the welds and in parent metal is schematically represented.

The research reported was planned to obtain basic information on the mechanism of cracking, and to evaluate the effects of differences in the metal and in processing variables. Various types of test for evaluation of cracking susceptibility were evolved; these are described and illustrated in the paper.

The materials used were various heats and forgings of niobium-stabilized 19-9 chromium-nickel steel, and straight 18-8 steel, and the electrodes were chosen to give weld metal of varying ferrite content.

The results confirm the relation between the cause of hot tearing in castings and weld cracking. They also support the considerable weight of evidence which has already demonstrated the effectiveness of suitable ferrite contents in minimizing weld cracking. Further, the test data afford statistical proof that the more highly austenitic the material

(on the basis of the Schaeffler stainless-steel constitution diagram) the greater is the ferrite content required for effective reduction in weld cracking. For example, electrodes containing 8 or 11 per cent. of ferrite may not be fully effective in eliminating weld cracking in highly austenitic steels, whereas for slightly austenitic compositions these electrodes may contain more ferrite than is required to eliminate cracking.

Additions of ferrite (in any amount) to the weld deposit have no effect in preventing hot cracking of the parent material.

As in the hot tearing of castings, base-metal cracks have been related with the liquation of fusible grain-boundary segregate regions. The heavy casting and forging sections which have the greatest tendency to base-metal cracking are of the extremely coarse-grained type, and provide conditions which are conducive to formation of grain-boundary segregates. (No attempt was made in this investigation to identify the elements and the composition of the segregate regions responsible for base-metal cracking.)

Thermally-cycled, simulated stress-rupture tests showed that ruptures with low ductility are possible, at both 1550° and 1750° F. (845° and 955°C.), for material containing microscopic notch-extension cracks when accompanied by stresses which are near to the yield point for the temperature involved. The thermal cycles used (which simulated heat-treatment cycles used for heavy-section welds) were not of sufficient duration to exhibit low-ductility rupture when the holding temperature was limited to 1150°F. (620°C.), and the exact limits of temperature within which the stress-rupture mechanism is operative were not determined. There are, however, indications that the range would be at least 1350°–1850°F. (730°–1010°C.). Variation in the cracking propensities of different heats of the niobium-stabilized chromium-nickel steel is attributed to development or dispersion of fusible-segregate regions, as the result of melting or processing variables.

Nickel-Chromium Alloy Coating of Exhaust Valves

HENRY WIGGIN AND CO. LTD.: 'Brightray-Coated Exhaust Valves.'

Publn. 299B, 1955; 8 pp.

This publication draws attention to the advantages of an 80-20 nickel-chromium alloy coating as a means of preventing corrosion of i.c. engine exhaust valves in contact with the products of combustion of leaded fuels. This method of coating was widely used during the war on the exhaust valves of aero engines, and experience gained during that period led to its adoption also for coating valves of various types used in automobiles. In addition to the enhanced corrosion-resistance which it confers, the nickel-chromium alloy coating has the advantage that it is easily deposited (requiring no flux), the deposit can be machined close to the required size on an ordinary lathe, and only surface finishing of the actual seat face is required on the grinder, and the cost of coating is low. B.A.C. Brightray is a grade of 80-20 nickel-chromium alloy which has been specially developed to ensure maximum ease of deposition and consistent reliability of results in this application.

In this small manual details are given of preparation of the valve, equipment required for the coating operation, method of applying the coating, and machining of the coated valve. The publication is well illustrated with drawings demonstrating the procedure recommended, and with photographs of valves (uncoated and Brightray-coated) after engine service.

Nickel-Chromium-Boron Coatings: Technique of Application

D. G. MOORE and J. R. CUTHILL: 'Protection of Low-Strategic Alloys with a Chromium-Boron-Nickel Cermet Coating.'

Amer. Ceramic Soc. Bull., 1955, vol. 34, Nov., pp. 375–81, 382.

During recent years nickel-chromium-boron hard facings have been increasingly used for metal parts subjected to severe conditions of erosion and oxidation. Two methods have been employed for applying the coatings: (1) flame spraying and subsequent fusing of the coating to the base metal with an oxyacetylene torch, and (2) dipping the part into, or spraying it with, a suspension prepared by mixing powdered nickel-chromium-boron with a plastic resin, and fusing by heating in a hydrogen atmosphere.

The authors concede that the flame-spraying method is suitable in many cases, but they point out its limitations, specifically mentioning its cost (for large-scale use), its unsuitability for coating cylindrical parts of small inside diameter, and the fact that results are not satisfactory when thin layers of the order of 0·002 in. are required. It is urged that the usefulness of such hard facings could be much extended by applying the coating material by methods similar to those employed in application of ceramic coatings. It is suggested that the coating should be prepared by ball-milling the nickel-chromium-boron powder with frit, clay and water, to form a water suspension, or 'slip'. The slip would be applied to the part by dipping, spraying or slushing and, after drying, the coated material would be fired at a temperature above the melting point of both the metal powder and the frit.

This paper presents a detailed account of experiments carried out to develop this idea, and to determine the properties and protective value of coatings so produced. The powder used was within the following percentage limits of composition:—chromium 13–29, boron 3–5, nickel 65–75, iron + silicon + carbon 10 max.

Three basis materials were used in most of the experiments: ingot iron and two low-alloy steels. One of the steels was a 2 per cent. chromium type intended for use at temperatures up to 1200°F. (650°C.), such as would be encountered in heat-exchanger units and in hot piping in oil refineries: the other was a precipitation-hardening grade of chromium-molybdenum-vanadium steel currently used for rotors in the compressors of aircraft gas turbines, and for aircraft brakes.

The composition of the coating material developed as optimum is given (parts by weight) as nickel-chromium-boron powder 90, frit powder (of given composition) 10, enamelling clay 5, water 25. Two grades of this mixture were developed, designated respectively M60 and M60F.

Coating thicknesses in the range 0·005–0·010 in. can be made with single applications: for thicknesses above 0·010 in. multiple coats are recommended. For very thin coatings finer grinding of the slip is necessary: in preparation of the M60F modification ball milling was for seventeen hours (as compared with the one-hour treatment used for the M60 grade), and it was found possible, with the F-type mixture, to apply coatings at a fired thickness as low as 0·001 in. Firing of the coatings was at 1900°–2000°F. (1035°–1095°C.), in a combustion-gas atmosphere. During the firing the cermet particles melt to form a continuous layer and this layer becomes brazed to the surface of the basis material.

Heating tests of the coated steels showed that cermet layers of this type, in thicknesses as low as 0·002 in., provide protection against oxidation for more than 800 hours at 1500°F. (815°C.). The coatings are characterized by moderate ductility and excellent resistance to thermal shock.

Calculation of Gamma Radiation Induced in Reactor Materials

See abstract on p. 56.

PATENTS

Calcium-Nickel Phosphate Catalysts

Catalysts containing as the principal ingredient calcium-nickel phosphate are specially effective in selectively catalyzing the thermal dehydrogenation of hydrocarbons, especially normal butylenes, without causing extensive cracking or other decomposition of the hydrocarbons. Method of preparation of the catalysts is covered.

DOW CHEMICAL CO. *Brit. Pat.* 746,611.

Reactivation of Poisoned Catalysts

Hydrogenation catalysts of nickel, cobalt, copper, iron or platinum metals which have been poisoned with sulphur, phosphorus, selenium, tellurium, arsenic or antimony compounds are regenerated by treatment with a liquid which dissolves the poison, but which does not chemically attack the poison or the catalyst. Preferred media are cyclohexene, benzene, ethylenic substances, or acetone.

E. B. MAXTED and G. T. BALL. *Brit. Pat.* 744,049.

Bright Nickel Plating

A bath for the electrodeposition of bright nickel deposits contains (g./L.) a nickel salt 17–233, one organic compound forming sulphonated phthalide or naphthalide 2–20, and a salt of zinc, cadmium or thallium 0·1–1. Typical compositions are given.

ROCKWELL SPRING AND AXLE CO. (inventors, C. L. FAUST and W. H. SAFRANEK). *French Pat.* 1,104,411.

Maintenance of Electroless Plating Solutions

The hypophosphite in an electroless nickel-plating bath is replenished by adding hypophosphorous acid and treating the bath with an anion-exchange material to remove the phosphite ions produced during the process. The anion-exchange material preferably contains at least one active amine or hydroxy group.

R. A. SPAULDING, assignor to GENERAL MOTORS CORPN. *U.S. Pat.* 2,726,968.

According to a further patent, the nickel concentration in a hypophosphite bath is replenished by adding a water-insoluble nickel compound (preferably oxide, hydroxide or carbonate) and treating the bath with an anion-exchange material, to remove phosphite.

R. A. SPAULDING, assignor to GENERAL MOTORS CORPN. *U.S. Pat.* 2,726,969.

Heat-Treatment of Nickel-Aluminium Bronzes

Complex aluminium bronzes containing aluminium 8–12, per cent., and optionally up to 8 per cent. of one or more of the elements iron, nickel, cobalt and manganese, are improved (with special reference to homogeneity and fatigue-resistance) by the following heat-treatment:—heating at 800°–1050°C. to bring the material into the β condition, in which substantially the whole of the aluminium is in solid solution, and quenching to below 600°C., virtually to retain this condition and to ensure that any α particles which may be present are in the form of a fine dispersion. After such treatment the alloy may be re-heated for final hot working or forging to finished shape: alternatively, after quenching and prior to final hot working, the material may be heat-treated within the range 400°–800°C., by which means the quantity and distribution of the α particles can be more closely controlled.

LANGLEY ALLOYS, LTD. (inventor, W. H. RICHARDSON). *Brit. Pat.* 743,321.

Nickel-Aluminium-Bronze Piston Rings

Piston rings for internal combustion engines having, among other properties, improved resistance to corrosion by sulphur-containing fuels, are made from copper-base alloys containing aluminium 5–15, nickel 2–8, iron 2–8, manganese 0·25–8, per cent. Thermal treatment comprises heating at 860°–910°C. for up to two hours, tempering (preferably by re-heating at 350°–450°C.), and quenching.

SPECIALLOID, LTD. (inventor, T. O. HUNT). *Brit. Pat.* 744,523.

Nickel-Rhodium Alloy for Electron-Tube Grids

Grids for electron tubes are made from wire (0·0004–0·0015-in. diameter), of an alloy containing rhodium 30–50, nickel 44–70, tungsten or molybdenum 0–6, per cent.

E. COHN. *U.S. Pat.* 2,729,763.

Welding of Copper-Nickel Alloys

In shielded-arc welding of copper alloys containing nickel 5–30 per cent. porosity is prevented by using a filler material similar in composition to the parent alloy but containing also aluminium and/or titanium 0·1–1 per cent., preferably 0·2–0·5 per cent.

E. A. TAYLOR and IMPERIAL CHEMICAL INDUSTRIES, LTD. *Brit. Pat.* 745,829.

Nickel in Brazing Alloys

The following compositions are cited as brazing alloys suitable for joining steel, copper, cast iron, brass or bronze:—silver 0·2–12, copper 43–50, nickel 9–12, silicon and/or manganese and/or phosphorus 0·1–1, per cent., zinc balance. Tin and/or cadmium (0·1–15, per cent.) and iron (0·5–0·75, per cent.) may also be present.

R. D. WASSERMAN and EUTECTIC WELDING ALLOYS CO., LTD.
Brit. Pat. 745,234: similar to *French Pat.* 1,077,373.

Nickel-base Alloy Thermocouple Elements

The negative element of a thermocouple is made from an alloy containing 1·5–3 per cent. of silicon; 0·01–2 per cent. of one or more of the elements cobalt, iron, titanium, zirconium, tantalum, copper, chromium, tungsten, molybdenum; small amounts of alkaline-earth or rare-earth metals, and manganese 0–3 per cent., nickel balance. It is claimed that by adding the small amounts of earth metals the thermoelectric force is moderately influenced and can be exactly graduated.

A. B. KANTHAL. *Brit. Pat.* 746,274:
similar to *Swiss Pat.* 307,385,
„ „ *French Pat.* 1,046,219.

Carburizing of High-Alloy Steels

Parts made from steel of the composition given below are surface hardened by carburizing (preferably at 900°–1200°C.) for up to 12 hours with a mixture of wood charcoal and barium carbonate or potassium cyanide), quenching from 950°–1150°C., and tempering at 300°–650°C. The composition ranges for the steel are chromium 9–14, nickel 0–5, molybdenum 0–5, cobalt 0–5, tungsten 0–5, carbon up to 0·3, silicon up to 1, manganese up to 1, sulphur and phosphorus up to 0·045 each, per cent., iron balance.

BRISTOL AEROPLANE CO., LTD. (inventors, E. R. GADD and P. H. FRITH). *Brit. Pat.* 745,013.

High-Temperature Low-Cobalt Alloys

The rupture strength of warm-worked austenitic cobalt-free alloys, or alloys containing less than 30 per cent. of cobalt, is substantially improved by the addition of a small amount of boron. It is specified that where both nickel and cobalt are present, the total shall be not more than 45 per cent. Detailed compositions are cited.

W. JESSOP AND SONS, LTD. (inventors, G. T. HARRIS and H. C. CHILD).

Brit. Pat. 746,472: similar to *Belgian Pat.* 531,998;
„ „ *French Pat.* 1,106,608.

Niobium and Tantalum Additions to High-Temperature Precipitation-Hardening Alloys

In nickel-chromium-iron-base precipitation-hardenable high-temperature alloys containing titanium small percentages of niobium and/or tantalum are added, in order to increase the amount of carbon which can be present without deleterious effect on the nickel-titanium precipitation-hardening complex. The following limits of composition are given: carbon up to 0·15, nickel 20–26, chromium 11–15, cobalt 0–2, niobium and/or tantalum 0·2–0·8, molybdenum 2·3–3·3, titanium 1·5–2·5, per cent., iron balance.

W. JESSOP AND SONS, LTD. (inventors, G. T. HARRIS and H. C. CHILD). *Brit. Pat.* 745,898.

Wrought Steel for High-Temperature Service

Steel of the composition shown below is free from delta iron when quenched from 2150°F. (1175°C.), and is claimed to have high creep and rupture strength and ductility at 1300°F. (705°C.). Composition range is chromium 10–20, manganese 5–10, molybdenum 4–8, nickel 10–20, carbon 0·1–0·08, per cent., iron balance. Silicon up to 1, and nitrogen 0·1–0·2, per cent., may also be present.

M. FLEISCHMANN, assignor to
TIMKEN ROLLER BEARING CO. *U.S. Pat.* 2,724,647.

Heat-Resisting Steels for Valves and Valve Parts

Internal-combustion engine valves and valve parts are made from a steel showing high hardness at operating temperatures, and claimed to be particularly resistant to hot corrosive atmospheres such as those containing the combustion products of anti-knock petrols, e.g., of the tetraethyl-lead type.

The composition range is as follows:—carbon 0·08–1·5, chromium 12–30, nickel 2–35, manganese 3–12, nitrogen 0·06–0·6, silicon not more than 0·45, per cent., iron balance. Special attention is directed to the influence of the individual elements on the properties of the steel, e.g., to the effect of high nitrogen on hot hardness and resistance to corrosion by lead oxide.

ARMCO INTERNATIONAL CORPN. (inventor, P. A. JENNINGS).
Brit. Pat. 744,599 (similar to *Australian Pat.* 165,077).

Nickel-Alloy Cathodes in Electrolytic Extraction of Manganese

It has been found that nickel-base alloys containing molybdenum, chromium, iron and tungsten are highly resistant to corrosion by aqueous solutions of manganese and ammonium mineral salts, the electrolyte employed in most processes for electrowinning of manganese. Further, such alloys, when used as cathodes, maintain their polished surfaces for very long periods: they also permit easy stripping of the electrodeposited manganese. According to the present invention, cathodes in an electrolytic cell used in extraction of manganese are made from sheets of rolled, annealed, polished nickel-base alloy containing chromium (less than 30 per cent.), tungsten

(less than 10 per cent.), iron (less than 25 per cent.), molybdenum (less than 20 per cent.), balance nickel.

ELECTRIC FURNACE PRODUCTS CO., LTD., assignee of G. D. BAGLEY and M. C. CAROSELLA. *Brit. Pat.* 745,076.

Nickel-Silicon-base Corrosion-Resisting Alloys

The ductility of nickel-silicon-base corrosion-resisting alloys is improved by the use of the following composition:—silicon 4–10, tantalum 2–25, aluminium up to 3, copper up to 4, iron up to 15 (preferably less than 3), per cent., remainder nickel. Within the limits specified, silicon is in inverse ratio to tantalum. Up to 50 per cent. of the tantalum content may be replaced by niobium, with the proviso that the total of the two elements shall be not more than 25 per cent. High resistance to corrosion by sulphuric acid is characteristic of the alloys.

ELECTRIC FURNACE PRODUCTS CO., LTD. (inventors, W. O. BINDER and C. R. BISHOP). *French Pat.* 1,106,995.

Nickel in Tantalum-base Alloys for Pen Nibs

The following range of composition is cited for pen-nib alloys:—tantalum 35–90, nickel 10–60, boron 0·1–0·5, per cent. Tantalum may be replaced by up to 25 per cent. of niobium, and nickel by up to 20 per cent. of iron or cobalt, provided that the nickel is not less than 10 per cent. Typical compositions are given as:—

Tantalum %	Nickel %	Boron %	Gold %	Niobium %
78	20	2	—	—
52	45	2·5	0·5	—
57·5	30	2·5	—	10

W. C. HERAEUS, G.M.B.H. *French Pat.* 1,108,101.

Nickel-containing Alloys for Watch Springs

In watch springs made from an alloy to *British Patent* 733,510 (see *Nickel Bulletin*, 1955, vol. 28, No. 10, p. 170) a sufficiently high modulus of elasticity can be produced only by severe cold working. Such treatment is apt to produce a magnetic condition, and a structure less resistant to rusting than is desirable in this application. According to the present patent an austenitic nickel-chromium steel having a cubic-face-centred crystal lattice is homogenized, quenched, cold drawn, and cold rolled to strip so that the maximum value of the modulus of elasticity is orientated in the 111 direction and the latter is substantially parallel to the direction of rolling. The preferred composition is given as nickel 16, chromium 10–16, carbon 0·02, per cent., iron balance. The following elements may also be present:—manganese 1–2, molybdenum 0·5–5, tungsten 0–6, beryllium 0·01–1, titanium 0·1–2, per cent.

R. STRAUMANN. *Brit. Pat.* 745,106.

Titanium-Nickel Brazing Alloy

Titanium or titanium-alloy parts are bonded by interposing a nickel-containing layer (preferably a powdered titanium-nickel alloy containing 30–31 per cent. of nickel and having a particle size of 100–300 mesh), and heating the composite, preferably at 1850°–1860°F. (1010°–1015°C.) for 1½ hours, to cause diffusion.

A. L. BOEGEHOLD, C. W. VIGOR, assignors to GENERAL MOTORS CORPN. *Brit. Pat.* 746,648.

Flux for Fusion Welding of Nickel and Nickel Alloys

In the fusion welding of nickel and high-nickel heat-resisting alloys, sound welds are obtained by the use of a flux containing calcium fluoride and at least one alkali metal silicate. The preferred composition is within the following limits:—calcium fluoride 39–50, sodium silicate 50–61, per cent. by weight. The flux may be used in dry powder form or as a paste.

BRITISH OXYGEN CO., LTD. (inventor, C. COULSON-SMITH). *Brit. Pat.* 743,285.

Coating of Steel with Nickel-Boron Alloys

Precipitation of boro-hydrides from aqueous solutions of metal salts is a potential method for coating of steels with boron alloys, but difficulty has been experienced in obtaining adhesion of the coating. According to the present patent, steel is coated by reacting sodium boro-hydride with nickel chloride in a solution of ethanol, to form a precipitate of nickel boride, with which the steel is coated. The coated steel is then heated in a reducing atmosphere, resulting in formation of a nickel-boron alloy. Hydroxides may be incorporated in the reaction mixture, to render the solution more gelatinous.

J. C. WARF and K. H. SCHALTEGGER, assignors to SUPERWELD CORPN. *U.S. Pat.* 2,726,170.

Attention is drawn to the fact that many of the names of materials mentioned in The Nickel Bulletin are *Registered Trade Marks.*

PRINTED IN ENGLAND *by* WIGHTMAN MOUNTAIN LTD.
WESTMINSTER, LONDON, S.W.1